"UTILITY OF REAL TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN BALLOON MITRAL VALVULOPLASTY"

Dissertation submitted for

D.M. DEGREE EXAMINATION

BRANCH II – CARDIOLOGY

MADRAS MEDICAL COLLEGE

AND

GOVERNMENT GENERAL HOSPITAL

CHENNAI – 600 003

THE TAMIL NADU DR.M.G.R MEDICAL UNIVERSITY

CHENNAI – 600 032

AUGUST 2007

"learn to heal"

CERTIFICATE

This is to certify that the dissertation entitled **"UTILITY OF REAL TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN BALLOON MITRAL VALVULOPLASTY"** is the bonafide original work of **Dr.T. MUNUSAMY**, in partial fulfillment of the requirements for D.M. Branch-II (CARDIOLOGY) examination of THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY to be held in August 2007.The period of post-graduate study and training was from August 2004 to July 2007.

THE DEAN
MADRAS MEDICAL COLLEGE &
GOVERNMENT GENERAL HOSPITAL
CHENNAI - 600 003.

PROFESSOR V.JAGANATHAN M.D., D.M.
PROFESSOR AND HEAD OF THE
DEPARTMENT OF CARDIOLOGY
MADRAS MEDICAL COLLEGE &
GOVERNMENT GENERAL HOSPITAL
CHENNAI - 600 003.

DECLARATION

I **Dr.T.MUNUSAMY,** solemnly declare that this dissertation entitled, **"UTILITY OF REAL TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN BALLOON MITRAL VALVULOPLASTY"** is a bonafide work done by me at the department of Cardiology, Madras Medical College and Government General Hospital during the period 2004 – 2007 under the guidance and supervision of the Professor and Head of the department of Cardiology of Madras Medical College and Government General Hospital, Professor V.Jaganathan M.D.D.M. This dissertation is submitted to The Tamil Nadu Dr.M.G.R Medical University, towards partial fulfillment of requirement for the award of **D.M. Degree (Branch-II) in Cardiology.**

Place : Chennai

Date:

Dr.T. MUNUSAMY

ACKNOWLEDGEMENTS

A great many people made this work possible. I thank my Dean for allowing me to conduct this study.

My warmest respects and sincere gratitude to our beloved ***Prof V.Jaganathan*** *Professor and Head of the Department of Cardiology, Government General Hospital, Chennai who was the driving force behind this study. But for his constant guidance this study would not have been possible.*

My respectful thanks to ***Prof R.Alagesan*** *for his constructive ideas, personal guidance and involvement in this study.*

I am indebted to ***Prof. Geetha Subramanian, Prof A.Balaguru, Prof. B.Ramamurthy and Prof. P.Arunachalam*** *without whom, much of this work would not have been possible.*

I acknowledge ***Dr M.A.Rajasekar*** *for the many useful comments he made during this project.*

*In addition, I am grateful to****, Dr. G.Gnanavelu, Dr.D.Muthukumar, Dr.G.Karthikeyan, Dr.G.Palanisamy, Dr.P.S.Mohanamurugan, Dr S.Venkatesan Dr.K.Meenakshi, Dr.G.Ravishankar, Dr.Murthy, Dr.P.JustinPaul*** *for tracing all those waveforms and guidance.*

Last but not the least I thank all my patients for their kind cooperation.

CONTENTS

INTRODUCTION

Mitral valve is much more complex than the semilunar valve. The mitral valve consists of six major anatomic components: The posterior left atrial wall, annulus, leaflet, chordae tendinae, papillary muscles and left ventricular free wall. The circumference of the normal mitral valve ranges from 8 to 10.5 cm (Mean 9.4).

Mitral valve consists of two leaflets. The anterior leaflet has a much longer base to margin of closure width (2.3cm) than posterior leaflet (1.2cm), but the circumference (6cm) of the posterior leaflet (annular attachment) is about twice that of the anterior leaflet (3cm).

The anterior leaflet is large and semicircular, and it partially separates the ventricular inflow and outflow tracts. However, unlike its right-sided counterpart, it also forms part of the outflow tract. The posterior mitral leaflet is rectangular and is usually divided into three scallops[1, 2]. The middle scallop is the largest of the three in more than 90 percent of normal hearts. Occasionally, however, either the anterolateral or the posteromedial scallop is larger, and rarely there are accessory scallops.

Posterior mitral leaflet prolapse usually involves the middle scallop and may be associated with chordal rupture. Both mitral leaflets are normally similar in area. The anterior leaflet is twice the height of the posterior leaflet but has half its annular length[3]. With advanced age, the mitral leaflets thicken somewhat, particularly along their closing edges[4].

The commissures are cleftlike splits in the leaflet tissue that represent the sites of separation of the leaflets. Beneath the two mitral commissures lie the anterolateral and posteromedial papillary muscles, which arise from the left ventricular free wall. Commissural chords arise from each papillary muscle and extend in a fan-like array to insert into the free edge of both leaflets adjacent to the commissures (major commissures) [5] or into two adjacent scallops of the posterior leaflet (minor commissures). The attachments of commissural chords precisely demarcate the commissure.

The anterolateral papillary muscle is commonly single and usually has a dual blood supply from the left coronary circulation[6]. In contrast, the posteromedial papillary muscle usually has multiple heads and is most commonly supplied only by the right coronary artery. Small left atrial branches supply the most basal aspects of the mitral leaflets. Papillary muscle contraction pulls the two leaflets toward one another and thereby promotes valve closure.

The line of closure for either mitral leaflet is not its free edge but an ill-defined junction between a thin, clear zone and a thicker, rough zone. The major chordae supporting a leaflet insert into its free edge and rough zone. The chordae tendineae anchor and support the leaflets and, by doing so, prevent leaflet prolapse during ventricular systole. Two particularly prominent rough zone chords, referred to as strut chordae, insert along each half of the ventricular surface of the anterior mitral leaflet and tend to calcify with age. Unlike the tricuspid valve, the normal mitral leaflets have no chordal insertions into the ventricular septum.

Mitral stenosis (MS) an obstruction to blood flow between the left atrium and left ventricle is caused by abnormal mitral valve function. In virtually all adult patients, the cause of MS is previous rheumatic carditis.

Rheumatic fever results in four forms of fusion of mitral valve apparatus leading to stenosis: 1.Commissural 2.Cuspal 3.Chordal, and 4.combined.

The typical M-mode and 2D echocardiographic features of rheumatic mitral stenosis include the following.

1. Thickened and calcified mitral leaflet and subvalvular apparatus
2. Decreased E-F slope
3. "Hockey –Stick" appearance of anterior mitral leaflet in diastole
4. immobility of the posterior mitral leaflet
5. Fish mouth orifice in the short axis view
6. Increased LA size.

The mitral valve area can be measured by

1. Planimetry

2. Pressure-half time

3. Continuity equation

4. PISA (Proximal isovelocity surface area).

The following categorize the severity of mitral stenosis according to mitral valve area.

Normal, 4 to 6 cm^2

Mild, 1.6 to 2.0 cm^2

Moderate, 1.1 to 1.5 cm^2

Severe, $1.0cm^2$ or smaller

Mitral stenosis is considered severe when the

1. Resting mean pressure gradient is ≥10 mmHg
2. Mitral valve area is ≤ $1.0cm^2$
3. Pressure half time is ≥ 220 milliseconds.

Management of mitral stenosis includes 1. Medical 2. Surgical, and 3. Interventional therapies.

The interventional therapy is usually performed in patients with severe MS and occasionally in patients with moderate MS.In patients undergoing balloon mitral valvuloplasty (BMV), an echocardiographic score based on valve thickness, calcification, mobility and subvalvular thickening can be used to predict the outcome of the procedure. The patients with an echocardiographic score of 8 or less have a more favorable result from BMV than those with a higher score, but a score higher than 8 does not preclude the option of valvuloplasty. Commissural calcification or fusion is another important determination of poor outcome after percutaneous valvuloplasty or valvotomy.

Although conventional 2D echocardiography is still the gold standard for evaluating mitral stenosis during BMV, measurement of mitral valve area relics largely on the experiences of the observers, which at times may be inaccurate and not always reproducible, With the recent introduction of a novel, high speed, volumetric scanner system, realtime, 3D echocardiography (RT3DE) could be used to display the mitral valve and its relation to neighboring structures in real time. It has great potential in assessing morphological characteristics of the mitral valve apparatus and in determining the valve orifice are, combined with quantative analysis software during BMV.

REVIEW OF LITERATURE

The Inoue balloon catheter was the first catheter system developed for nonsurgical mitral valvuloplasty in patients with mitral stenosis[7]. As a result of extensive clinical trials, mitral valvuloplasty using the catheter, referred to as percutaneous transvenous mitral commissurotomy (PTMC) has become an effective and safe alternative to surgical treatments of patients with rheumatic mitral stenosis.

HISTORIC PERSPECTIVE

Beginning in the early 1960's several balloon catheter intervention techniques emerged as alternatives to surgical treatment of cardiovascular diseases. These included extraction of arterial emboli and thrombi, dilation of arteriosclerotic stenosis of peripheral vessels, and atrial septostomy for cyanotic congenital heart diseases. Inspired by these innovations, Inoue began to design and develop a new catheter system in 1976. A prototype double-lumen coaxial balloon catheter was perfected in July 1980 and was used to create an atrial septal defect in children with transposition of the great arteries, tricuspid atresia, and other types of cyanotic heart disease[8]. It also was used to treat membranous obstruction of the hepatic portion of the inferior vena cava and stenotic lesions in ileofemoral arteries[9].

The ability of the balloon to separate fused commissures of the mitral valve was evaluated under direct vision as an auxiliary means of open mitral commissurotomy in 1979[10].

The fused commissures were separated precisely along their natural lines without injury to the leaflets, tearing of the chordae tendineae, or creation of significant mitral regurgitation. The technique of inserting the balloon catheter across the mitral orifice by transseptal catheterization via the femoral vein was concurrently studied in canine experiments[11]. On June 3,1982, the first clinical application of the prototype balloon catheter was successfully achieved in a 33 year-old man with severe rheumatic mitral stenosis[12].

The prototype balloon catheter used in the early stage of clinical trials had a large-profile balloon that required a cut-down for insertion into the saphenous vein. Subsequent modifications in catheter design enabled percutaneous introduction of the catheter through the patient's femoral vein, and the procedure thus was named percutaneous transvenous mitral commissurotomy[13]. The groin entry site of the catheter in the past was dilated with a 16 Fr. dilator while the atrial septum was dilated with a 14 Fr. 70cm dilator. Further refinements reduced the catheter shaft size from 14 to 12 Fr. and combined the two dilators into a single 14 Fr.dilator that allowed simultaneous dilatation of the atrial septum and the femoral vein.

INOUE BALLOON CATHETER SYSTEM

The instruments used in PTMC consist of a balloon catheter and its accessories. Before execution of the PTMC procedure, the operator and assistants should familiarize themselves thoroughly with the structure and function of the Inoue balloon catheter system.

INOUE BALLOON CATHETER

The balloon catheter has a 12Fr. Polyvinyl chloride tube shaft with a coaxial double-lumen. The inner lumen of the catheter permits pressure measurements, blood sampling, and insertion of a metal tube, guidewire, or stylet. The outer lumen connects proximally with a two-way stopcock used to connect the catheter to an inflation/deflation syringe and a vent and distally with a balloon mounted at the end of the shaft. The balloon is made of double layers of latex tubing. The balloon can be used transformed to various shapes from its natural form to serve different functions. The balloon section is stiffened and slenderized when the rubber balloon is stretched by inserting a metal tube. The slenderized balloon allows a smooth entry of the balloon catheter into the femoral vein without the use of an introducer set. It also permits an easy passage of the catheter across the atrial septum. The balloon changes its shape in three stages, depending on the extent of inflation. Initially only the distal half inflates followed by the proximal half with a constriction remaining in the middle. The constriction finally disappears when the balloon attains full inflation.

AUXILIARY INSTRUMENTS

An 80-cm 18-guage metal tube; the tube is inserted to lock with the inner lumen tube, thereby stiffening the catheter tip. The catheter tip is slenderized further (diameter of 4.5 mm and length of 60 mm) by pushing the metal hub of the inner tube to a locked position.

A 70-cm, 14 Fr. Polyethylene dilator; It is used to dilate the atrial septum and the femoral vein at the same time.

A 180-cm, 0.025-inch stainless steel guide wire with coiled floppy tip; the guide wire is inserted through the transseptal catheter across the atrial septum to guide the balloon catheter to the left atrium.

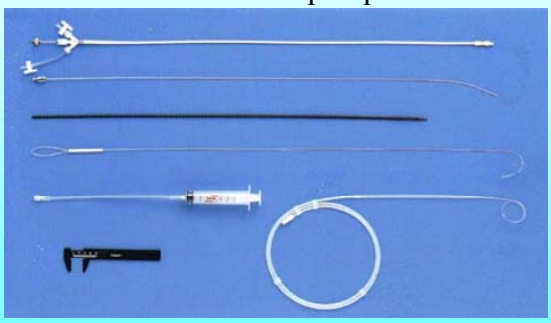
An 80-cm, 0.0038-inch high-torque J-tipped spring wire stylet; the stylet has a preformed J-shaped tip with a waist length of approximately 4.5 cm. After the balloon catheter is placed in the left atrium, the stylet is inserted, which provides excellent steerability and facilitates direction of the balloon tip toward the mitral orifice. Axial movement of the catheter is made by 1.1 torque control of the stylet. When the stylet is withdrawn from the catheter, the catheter tip advances forward, and vice versa.

A 30-ml plastic syringe and connecting tube; the extent of balloon inflation is controlled by adjusting the volume of diluted contrast material in the syringe, which is injected manually through a two-way stopcock.

A caliper; the caliper is used to measure the diameter of inflated balloons.

PTMC

- The instruments used in PTMC consist of a
  - Balloon catheter and its accessories
  - Instruments used for transeptal puncture



Before execution of the PTMC procedure, the operator and assistants should have thoroughly familiarized themselves with the structures and functions of the Inoue balloon catheter system.

Picture 1 Instruments of PTMC

PROCEDURE

Before BMV, anticoagulant therapy heparin 2500U always was given. The BMV was performed on fasting patients after premedication (10mg oral diazepam and 0.5 mg subcutaneous atropine). Appropriate intravenous fluid replacement was given routinely throughout the procedure the antegrade approach was used in all cases. A transeptal catheterization was performed via the right femoral vein, using a standard Brokenbrough needle, a Mullins sheath (8 Fr.USCI), and a dilator (Cook). The atrial puncture was carried out using anteroposterior and 30-degree right anterior oblique views, under continuous pressure monitoring. The interaterial septum was dilated using a peripheral angioplasty balloon 8 mm, in diameter. Finally, the balloon was positioned across the mitral valve, their position being confirmed by fluoroscopic detection of the mitral valve indentation during the first inflation.

Balloon size is chosen in accordance with the patients height (height in cm divided by 10 and added 10). The balloon is inflated sequentially. First the distal portion is inflated with 1 or 2ml of a diluted contrast medium and acts as the floating balloon catheter in crossing the mitral valve. Second, the distal part is further inflated and then the balloon is pulled back into the mitral orifice; inflation then occurs at the level of the proximal part and finally in the central portion, with the disappearance of the central waist at full inflation. A stepwise dilation technique under echocardiographic guidance is used[14]. The first inflation is performed 4 mm below the maximal balloon size is increased in steps of 2mm each.

The balloon then is deflated and withdrawn into the left atrium. If mitral regurgitation as assessed by color Doppler echocardiography, has not increased by over one grade and valve area, is less than 1cm^2 /m^2 of body surface area, the balloon is readvanced across the valve and PTMC is repeated with a balloon diameter increased by 2 mm larger.

The following criteria are used for ending the procedure: (1) mitral valve area greater than 1cm^2 /m^2 of body surface area (2) complete opening of at least one commissure or (3) appearance of mitral regurgitation or increment of regurgitation greater than one grade. After the procedure, the catheters were withdrawn immediately and manual compression was started. Heparin was continued subcutaneously for 24 hours and patients usually were discharged 2 to 3 days later.

MECHANISM

Mitral balloon valvotomy relieves mitral stenosis by splitting fused commissures, which is similar to surgical commisssurotomy. This mechanism has been demonstrated by pathologic specimens or intraoperative balloon dilation. Two dimensional echocardiography also has demonstrated cleavage of the mitral valve along the commissures after BMV. Such undesirable outcomes as leaflet tears, ruptured chordae, ruptured papillary muscles, and myocardial perforation could occur. The use of balloons too large for the size of the mitral annulus usually results in leaflet tears or separation of the mitral leaflet from the annulus.

COMPLICATION

Larger series are available and enable better assessment of the risk of complication in the BMV technique. **Procedural mortality** ranges from 0 to 3 percent in most series. The main cause of the death is left ventricular perforation or the poor general condition of the patient.

Mortality is higher in multicenter studies than in those from single large-volume centers, which reflects the importance of training.

The incidence of **hemopericardium** varies from 0.5 to 7 percent. Pericardial hemorrhage may be elated to transeptal catheterization or to apex perforation by the guide wires or balloon itself when exaggerated movement occurs. Here again, studies describing the practice of single groups report a lower incidence of hemopericardium than in multicenter studies. Several technical modifications have been proposed to lessen the risk of apex perforation: careful preshaping of the guide wires or their placement in the aorta; use of a combination trefoil and conventional balloon[15]. This seems to be more stable than two conventional balloons;

When it does occur, pericardiocentesis in the catheterization laboratory usually allows stabilization of the patient's condition and secondary transfer for cardiac surgery. Ramsdale and Schofield reported one case of endomyocardial trauma, without hemopericardium, caused by the rigid tips of the balloons. It resulted in transient hypotension, ST segment depression, and low cardiac output.

Embolism is encountered in 0.5 to 5 per cent of cases. It is very seldom the cause of permanent incapacitation and even more seldom the cause of death. Embolism may be cerebral or coronary in location, occurring mainly in the right coronary artery. It can be due to gas when it occurs immediately after balloon rupture, to fibrinothrombotic material, or, very seldom, to calcium. Although the incidence of embolism is low, its potential consequences are severe, and all possible precautions must be taken to prevent it. These include:

Full anticoagulation for at least 2 months before PTMC in cases of atrial fibrillation or if there is history of thromboembolic event. Careful detection of thrombi by using transesophageal echocardiography immediately before the procedure. This better images the left atrium, and especially the left atrial appendage, than does the transthoracic approach. When doubt persists, patients must exclude from PMC. Heparinization during the procedure, because recent transesophageal studies performed during PTMC have shown that transeptal catheter-related thrombi may occur during PTMC.

In most cases, the degree of **mitral regurgitation** remains stable or, more often, slightly increases after PTMC. Cases of mild increase in the degree of regurgitation are best shown by echocardiography, especially when using the transesophageal approach with color-flow Doppler. The small jets of regurgitation usually are localized in the open commissural area. They may be related to small tears in the leaflet, localized rupture of chordae, or incomplete closure of a rigid leaflet and shortened chordae tendineae after splitting of the commissure.

In the series of Essop et al. a prolapse of the anterior leaflet was responsible for a mild increase in mitral regurgitation in 23 per cent of patients with pliable valves. Finally, the role of transient traumatic or ischemic papillary muscle dysfunction has been posited but remains unproved. Conversely, in a few cases the degree of mitral regurgitation may clearly decrease, probably because of increased mobility of the leaflets.

Severe mitral regurgitation is rare, its frequency ranging from 2 to 19 per cent[16]. Surgical findings have shown that it is related to noncommissural tearing of the posterior or anterior leaflet. In these cases, one or both commissures are too tightly fused to be split. It also may be due to excessive commissural splitting, or in very rare cases to rupture of a papillary muscle. Severe mitral regurgitation can be observed in noncalcified valves, especially when unexpectedly abundant myxoid connective tissue is present at the site of rupture.

In our experience, anatomic findings at surgery showed that severe mitral regurgitation occurred in patients with unfavorable anatomy, because all had extensive subvalvular disease and half had valve calcification. Severe mitral regurgitation may be well tolerated, but in our experience more often it is not, and surgery on a scheduled basis is necessary. This is in agreement with previous surgical series, which have shown an unfavorable outcome in patients with mitral regurgitation occurring after commissurotomy. In most cases, valve replacement is necessary because of the severity of the underlying valve disease. Conservative surgery, combining suture of the tear and commissurotomy, has been performed successfully in cases with less severe valve deformity. In groups with good ex-

perience in mitral valve reconstruction, the need for valve replacement is more closely related to the extent of valve disease than to the tear itself.

The frequency of **atrial septal defect** reported[17], after PTMC varies from 10 to 90 per cent according to the technique used for its detection. Such shunts are detected in 10 to 30 per cent by the oximetry method, which lacks sensitivity when compared to the indicator dilution method, which gives an incidence of 62 per cent, and to color-flow Doppler imaging, in which shunts are shown in 38 to 90 per cent of cases.

The transesophageal approach, which allows excellent visualization of the whole septum, appears to be the most sensitive method. These shunts usually are small and restrictive, with high-velocity flow. *As* regards oximetry, this QP / QS ratio is over 1.5 in only 5 per cent and very seldom is over 2. Right-to-left shunts can occur on rare occasions in patients with elevated right heart pressures and pulmonary hypertension.

Recent studies have shown that shunting after PTMC is related to clinical variables (age, low cardiac output; valvular calcification, high echocardiographic score, previous surgical commissurotomy), to the valve area obtained after PTMC, and to technical factors (site of transseptal puncture, duration of the procedure, and type and size of balloon used). *As* regards the technical factors, Fields et al. have shown that, when using a two-balloon technique, the size of the atrial septal defect is minimized by a single transseptal puncture and the sequential withdrawal of the completely deflated balloons. Atrial septal defect also can be created by the inflation of the most proximal part of the balloon while inadvertently positioned

across the atrial septum, which may occur when a long balloon is used or when excessive traction is exerted to withdraw the balloon at full inflation.

The incidence of transient, **complete heart block** is 1.5 per cent, and it seldom requires a permanent pacemaker. After the transvenous approach, ***vascular complications*** are the exception. Urgent surgery (within 24 hours after PMC) is seldom needed for complication resulting from PMC. It may be required, however, for massive hemopericardium resulting from left ventricular perforation unresponsive to pericardiocentesis, or less frequently, for severe mitral regurgitation leading to hemodynamic collapse or refractory pulmonary edema.

Overall, when performed by experienced teams on properly selected patients, PMC is of relatively low risk. Furthermore, the procedure is not accompanied by the usual perioperative events (i.e., morbidity, infectious disease, chest wall damage, or pericarditis), and by the later thromboembolic, infectious, and degenerative complications that may occur when valve replacement has been performed.

TRANS THORACIC ECHOCARDIOGRAM

All patients with symptomatic mitral stenosis are potential candidates for BMV. The two dimensional and Doppler echocardiographic examinations is the most important test to identify which patients should have the procedure. An echocardiographic score has been developed in which valve rigidity; valve thickening, valve calcification, and subvalvular fibrosis are graded 0 (least) to 4 (most). The sum of the four components then gives an echocardiographic score.

If the cumulative score is 8 or less, the patients are generally a good candidate for BMV. If the score is greater than 9 but less than 12, the results of BMV are variable, although patients can still be considered candidates for the procedure. If the echocardiographic score is 12 or more, BMV should only be undertaken if mitral valve replacement is contraindicated. The results of BMV in patients with severe valve thickening, rigidity, calcification, and severe subvalvular fibrosis are not satisfactory. Evidence of left thrombus, a recent embolic event, severe mitral valve calcification, or severe subvalvular thickening and fibrosis are contraindications for BMV.

The presence of left ventricular thrombus in an area of an old myocardial infarction (if the patient has associated coronary artery disease) is also a contraindication because the thrombus can be dislodged by passage of the guidewires or the dilating balloons into the left ventricle. Since atrial fibrillation increases the likelihood of left atrial thrombus, patients with atrial fibrillation should receive anticoagulation therapy for 2 to 3 months before BMV and

echocardiography should show no evidence of left atrial thrombus before the procedure is undertaken.

A transesophageal echocardiogram should be performed if there is doubt as to the presence or absence of left atrial thrombus. If left atrial thrombus is suspected, BMV should not be performed. Instead, 2 to 3 months of additional anticoagulation therapy with warfarin is indicated, with repeat echocardiographic examination thereafter.

Grading of characteristics of mitral valve morphology from echocardiographic examination

Leaflet mobility

Grade 1. Highly mobile Valve with restriction of only the leaflet tips

Grade 2. Mid-portion and base of leaflets have reduced mobility

Grade 3. Valve leaflets move forward in diastole mainly at the base

Grade 4. No or minimal forward movement of the leaflets in diastole

Valvular thickening

Grade 1. Leaflets near normal (4-5mm)

Grade 2. Mid-leaflet thickening, marked thickening of the margins(5-8mm)

Grade 3. Thickening extends through the entire leaflets (5-8mm)

Grade 4. Marked thickening of all leaflet tissue (>8-10mm)

Subvalvular thickening

Grade 1. Minimal thickening of chordal structures just below the valve

Grade 2. Thickening of chordae extending up to one third of chordal length

Grade 3. Thickening extended to the distal third of the chordae

Grade 4. Extensive thickening and shortening of all chordae extending down to the papillary muscle

Valvular calcification

Grade 1. A Single area of increased echo brightness

Grade 2. Scattered areas of brightness confined to leaflet margins

Grade 3. Brightness extending into the mid-portion of leaflets

Grade 4. Extensive brightness through most of the leaflet tissue.

THREE DIMENSIONAL ECHOCARDIOGRAM

Whereas, conventional two dimensional (2D) Echocardiography is crucial to our understanding of the complex anatomy and three dimensional (3D) spatial relationships of cardiac structures, it requires the mental integration of a limited number of 2D imaging planes. This mental 3D reconstruction is inherently variable according to observer experience and expertise, and can only be described to other clinicians (such as surgeons) rather than

displayed reproducibly. The display of cardiac anatomy in three dimensions from any perspective would have clear advantages over conventional 2D imaging and provide an insight into the functional and anatomic properties of cardiac structures.

Recent advances in ultrasound and computer technology have been combined such that dynamic 3D echocardiographic imaging is now a practical reality. Three dimensional echocardiography (3DE) has been shown to be more accurate than 2DE in the quantification of cardiac volumes[18]. These studies used either manually contoured, static "wire frame" reconstructions or dynamic "volumetric" automated reconstruction technology that is now commercially available—we concentrate on the latter methodology in this review.

The benefits of 3DE are particularly well suited to the study of the mitral valve given its complex morphology and the importance of delineating its anatomy precisely in various pathological states. This was shown by Levine *et al* who used wire frame reconstruction of the mitral valve to define the 3D morphology of the mitral annulus and its relationship to mitral leaflet position, thereby clarifying the echocardiographic

definition of mitral valve prolapse[19]. The assessment of patients with mitral valve disease is one of the most promising clinical applications of this technology.

DATASET ACQUISITION, PROCESSING AND RECONSTRUCTION

A 3D dataset is composed of anatomical information from multiple 2D cross sectional

images. For reconstruction of the mitral valve in adult patients, transthoracic echocardiography (TTE) is the routine approach for 2D image acquisition as it offers a relatively stable site for the imaging probe and superior resolution of the mitral valve apparatus. Images from transthoracic echocardiography (TTE) are interfaced with a 3D computer system which incorporates the steering logic for acquisition of a rotational dataset and software for 3D reconstruction and display.

Optimal temporal and spatial registration is achieved by ECG and respiratory gating. Offline processing involves the conversion from polar to cubic Cartesian co-ordinates and interpolation of missing information between 2D slices. From the resultant dataset, novel 2D cut planes in any orientation can be selected (any plane echo) and multiple parallel cross sectional 2D slices can be generated in any desired plane (Para plane echo). A volume rendered 3D image of the mitral valve can be reconstructed from any perspective. Threshold limits are used to separate cardiac structures from blood pool and background.

Brightness and shading provide perception of depth. With the added dimension of time we

are able to study in detail the motion of the valve during the cardiac cycle.

IMAGE DISPLAY AND ANALYSIS

The digitized data were reformatted and interpolated into a cubic data set by filling in the gaps between pixels to create individual volume elements or voxels. This cubic data set could then be rotated in any direction, allowing unlimited cut planes irrespective of the original ultrasonographic window. Once a cut plane was chosen, a volume-rendered three-dimensional image was produced by a combination of distance, gradient and texture shading. For our study a short-axis view of the left ventricle at the level of the papillary muscle was used to view the mitral valve (as if looking up from the left ventricle into the valve).

The mitral valve leaflets, annulus and commissures were identified, inspected and compared in both the prevalvuloplasty and postvalvuloplasty studies. The mitral valve area was also measured by planimetry in this view. Several tomographic images of the valve orifice during diastole were inspected, and the image with the smallest mitral valve orifice was used. This was compared with the mitral valve area calculated by the pressure half-time method from the continuous-wave Doppler tracing of the mitral inflow velocity obtained from the two-dimensional TTE. The degree of mitral regurgitation was estimated from the color Doppler signal, also obtained from the two-dimensional TTE.

MITRAL STENOSIS

In managing patients with mitral valve stenosis, it is essential to obtain reliable information about mitral valve structure and area[20] although conventional 2-dimensional echocardiography is still the gold standard for evaluating mitral stenosis (MS) in clinical use[21]. Measurement of the mitral valve area (MVA) relies largely on the experiences of the observers, which at times may be inaccurate and not always reproducible. With the recent introduction of a novel,

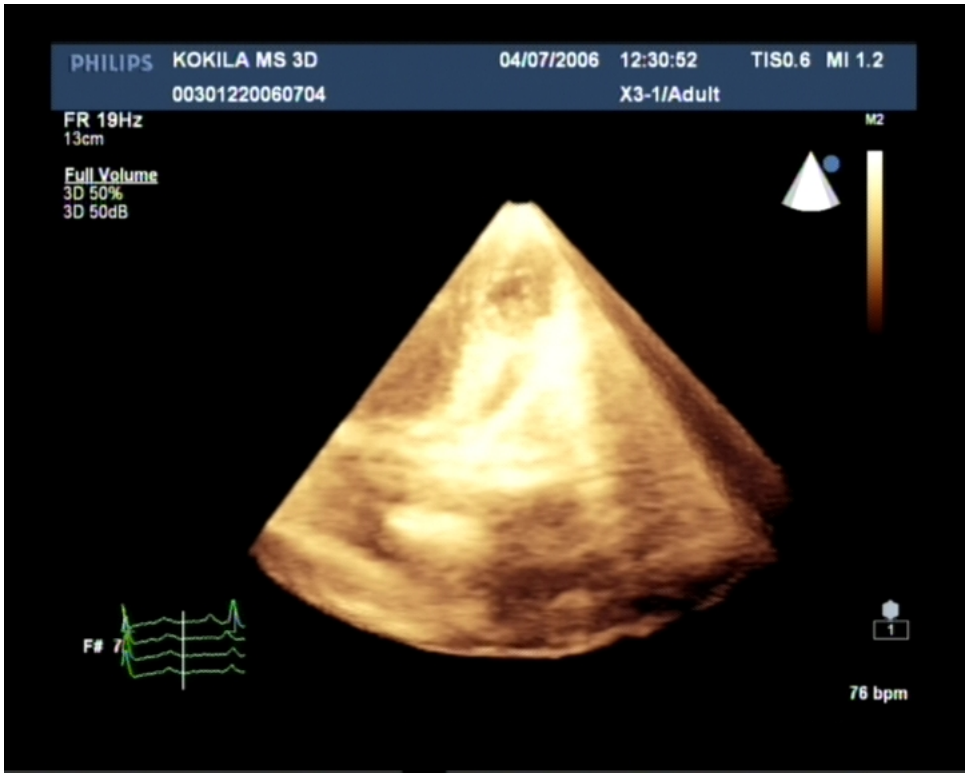
high-speed, volumetric scanner system, real time, 3-dimensional echocardiography (RT3DE) could be used to display the mitral valve and its relation to neighboring structures in real-time. It has great potential in assessing morphologic characteristics of the mitral valve apparatus and in determining the valve orifice area, combined with quantitative analysis software.

Two-dimensional Echocardiographic examinations were performed with patients in the left lateral decubitus position. Electrocardiograms were simulta-neously recorded in all subjects. A standard Parasternal left ventricular short-axis (mitral valve level) view was obtained, adjusting the transducer for optimal mitral valve orifice.

The MVA was traced point by point along the mitral valve endocardial border. Then we selected the apical 4-chamber view, placed the sample volume at the mitral valve orifice, recorded the diastolic flow spectrum, and calculated the pressure half-time (PHT) (MVA was calculated as 220/PHT).

New ultrasound equipment (Philips iE.33) was used to permit RT3DE of a mitral valve in the parasternal, apical, and sub costal views, We carefully adjusted the mitral valve to the center of the screen, opened the "live 3D" functional button, acquired pictures in real-time, then randomly rotated the picture, carefully observing the mitral valve apparatus and its relation to the neighboring structures. During the examination we paid special attention to adjusting the parameters to optimally display the 3-dimensional mitral valve structure at any given time. Sometimes the scanner angle (60° X *15°)* was not enough to display the whole mitral valve orifice,

Then the "full volume" program was used. With a standard apical 4-chamber view, we adjusted the mitral valve to the center of the screen, then opened the full-volume button, asked the subject to hold his/her breath, then acquired the "pyramid," 3-dimensional database (80° X 90°) from sequential 4 cardiac cycles. All images were stored on disks for off-line analysis.



Picture 2: Full volume 3D acquisition image in 4 beats ($80X90^0$)

Data are presented as mean ± SD for descriptive statistics. We chose the average values for 3-time measurements. The linear regression analysis and paired Student's *t* test were used. To assess the effect of intra- and interobserver variabilities on the 3-dimensional measurements of the MVA, 10 randomly

selected patients in the MS group were analyzed twice by one observer and at different times by two independent observers. A p value <0.05 was considered statistically significant[22].

The 3-dimensional structures of the mitral valve in 64 subjects were clearly and vividly demonstrated. We were able to observe the morphologic appearance of the mitral valve apparatus and its relation to neighboring structures from a different azimuth and angle using a randomly rotated mode in the live 3-dimensional program.

The normal mitral valve orifice in the birds-eye view from the left ventricular side demonstrated the intact mitral valve apparatus with tenuous valve leaflets and free mobility. However, mitral valve orifices in patients with MS were obviously smaller than those in normal controls; parts of the contracted mitral valve orifice in patients with MS were calcified with fused and thickened leaflets.

With the recent introduction and successful application of percutaneous balloon valvuloplasty for nonsurgical relief of symptomatic MS[23], it is crucial to obtain accurate measurement of the MVA. Two-dimensional echocardiography has been the standard method to determine MVA in routine clinical practice.

Because two dimensional echocardiography is limited by the quality of the acoustic window and the experience of the operator; the accuracy and reproducibility of valve area measurement is suboptimal.

In clinical situations, the symptoms of patients with MS and the pressure measurements obtained at cardiac catheterization were often not in agreement

with the area measurements from 2-dimensional echocardiography. The main reason for this discrepancy is the difficulty in acquiring the plane of the smallest MVA on routine examination. Furthermore, traditional 2-dimensional echocardiography could only image the MVA in a 2-dimensional plane; however, the asymmetry and complex structure of the mitral valve make it difficult to determine the MVA, which is not located in the same plane.

Compared with the 2-dimensional technique, both static and dynamic 3-dimensional echocardiography provides more information about cardiac anatomic structures without any arbitrary geometric assumptions[23]. However, this complex acquisition and off-line data processing proved cumbersome and impractical for routine clinical use. With the new development of RT3DE, it became possible to rapidly evaluate the mitral valve structure and area. RT3DE with a high-speed volumetric ultrasound system developed at Duke University is based on the use of a 16:1 parallel processing schema from a 2- to 4-MHz matrix, phased-array scanner. The 16.times improvement in the data acquisition rate allowed one to interrogate an entire 3-dimensional pyramidal volume in real-time.

Images in the region of interest may be viewed in real-time or in a 7 cardiac-cycle-captured volume without respiratory and electrocardiographic control. This novel, real-time, 3 dimensional echocardiography systems is now available for clinical use.

Three dimensional echocardiography has a role in both the quantitative and qualitative assessment of mitral stenosis. Three dimensional echocardiography

overcomes the limitations of image plane positioning inherent in conventional 2DE and offers a more precise

approach to measurement of mitral valve area. Para plane 3DE allows the 2D short axis slice in the optimum plane of the orifice to be selected from the 3D dataset and the smallest Complete orifice can be directly measured by planimetry. Anterior leaflet calcification often produces acoustic shadows which obscure the mitral orifice in the 2D transthoracic short axis plane. Chen *et al* assessed 15 patients with mitral stenosis and showed this

technique to correlate more closely with the Doppler pressure half time derived area compared with 2D echo planimetry.

The shape of the mitral valve leaflets proximal to the orifice has an impact on the flow dynamics across a valve. 3DE with stereolithographic modeling has been used to demonstrate that flat shaped valves cause a higher pressure gradient for the same anatomic area and flow rate compared with “funnel” shaped valves. Thus, 3DE provides insights into mitral leaflet geometry which could refine our assessment of mitral stenosis.

3DE also appears to be of value in the assessment of patients undergoing balloon mitral valvotomy (BMV) where the dominant mechanism is splitting of fused mitral commissures. Studies using 2DE have shown that commissural morphology is a powerful predictor of outcome after BMV and at our institution this forms the cornerstone of assessment of patients with mitral stenosis referred for valvotomy. Viewed from the left atrium, 3D reconstruction of mitral stenosis displays the restricted orifice, thickened leaflet margins and prominent left atrial appendage. In our experience, the volume rendered 3D display provides improved visualization of mitral commissural fusion, particularly when the leaflets are viewed from the perspective of looking upwards from

the left ventricle. Following balloon valvotomy, 3DE also defines clearly the extent and site of commissural splitting which may be symmetrical or eccentric.

LIMITATIONS OF THREE DIMENSIONAL ECHOCARDIOGRAPHY

The standard of the 3D reconstructed display depends critically on the quality of the original 2D cross sectional images. Until recently, in adult patients, this necessitated TEE. However, the development of harmonic imaging has made it feasible to reconstruct from a transthoracic rotational dataset. Minor movements of either patient or operator will distort the images and result in dropout which may be misinterpreted.

Atrial fibrillation or a variable respiratory pattern prolongs the acquisition time and impairs the dataset resulting in artifact. Operator dependent changes in threshold settings, which define the tissue–blood interface on the 3D rendered display, can affect the apparent mitral orifice.Therefore; measurements on reconstructed images should be made with caution

Spontaneous echo contrast in mitral stenosis hinders reconstruction of the valve from the left atrial perspective; this can be minimized by reducing the probe frequency. Highly mobile structures such as a ball valve thrombus, vegetations, and ruptured chords are not easily seen. In our opinion, 3DE has not improved visualization of the mitral subvalvar apparatus and areas of calcification are not apparent in the volume rendered display. At present this technology provides information which complements that gained from a comprehensive 2D and Doppler echocardiographic study.

AIM OF THE STUDY

Three-dimensional echocardiography is a recently developed, evolving imaging technique that allows visualization of intra cardiac structures from any perspective.

This study aims at utilizing real time three-dimensional transthoracic echocardiography (RT3DE) technique for comprehensive assessment of

- cardiac anatomy
- cardiac pathophysiology
- pathomorphology

in patients with rheumatic mitral stenosis who underwent Balloon mitral valvotomy (BMV).

STUDY DESIGN

This study was performed in the Department of Cardiology, Government General Hospital, Chennai, during the year 2004 – 2007.

STUDY INDICATION

Study indication was for the comprehensive assessment of cardiac anatomy and pathomorphology of rheumatic mitral stenosis who undergoes balloon mitral valvotomy.

STUDY GROUP SELECTION

Study groups are those who were referred and admitted for the management of rheumatic mitral stenosis.

Candidates for balloon mitral valvotomy were carefully evaluated by history taking, physical examination and laboratory tests, including electrocardiography chest radiographs, and echocardiography. Color Doppler two-dimensional echocardiography is essential to evaluate mitral valve morphologies and assess the degree of mitral regurgitation. Transesophageal echocardiography is performed to verify the presence or absence of left atrial thrombi.

EXCLUSION CRITERIA

1. Mitral regurgitation – moderate and more
2. Moderate and more calcification of mitral valves
3. Fresh left atrial thrombus
4. thrombus on atrial septum

5. Mobile thrombus

STUDY POPULATION

The study group consisted of 35 rheumatic mitral stenosis (severe) patients consisting of 21 males and 14 females, (mean age = 32.3+ 9.2 years, range = 22 to 45 years); The purpose and methodology were explained to the study subject in detail, and informed consent was obtained.

All the patients were subjected to clinical examination, ECG, X-ray chest, TTE and 3D Echocardiogram prior and post to balloon mitral valvotomy. TEE was done in selected individual to rule out LA clot. (n=5)

CLNICAL EVALUATION

The patients were either in class II (21out of 35, 60%) or in class III (14 out of 35, 40%) of the New York Heart association functional classification. All patients underwent thorough clinical evaluation before the study. One patient underwent prior BMV 9 years back. None of the study patients were on anticoagulant or antithrombotic drug therapy, and all were on mild oral diurectic, oral penicillin's and potassium chloride syrups. Complete haemogram and basic blood biochemical analysis were normal in all the subjects. All the baseline clinical characteristics and investigate parameters of the study population are listed in the Table (1) & (2)

Age	22 – 45 years
NYHA	II – III
Left atrial size(mm)	4.5 ± 3.2
MVO planimetry(cm^2)	0.7 ± 0.17
MVO PHT (msec)	325 ± 60
Wilkins score	3 ± 2
Pulmonary artery pressure(mmHg)	59.8 ± 18.6 / 39.0 ± 13.5
Mitral	PG 25 ±8.18 MG 16.1 ±5.36

Table-1: Baseline and 2D echocardiographic characters of patients

Pressure data of BMV (mmHg)

Aorta	106 / 74 / 50
LV	118 / 10
PA	90 / 61 / 42
RV	90 /14
LA	42 / 27 / 19
	(a) (mean) (v)

Table-2: Baseline haemodynamic characters of patients

METHODOLOGY

ECHOCARDIOGRAPHY STUDY

All the subjects in the study population underwent both transthoracic 2D and 3D echocardiographic examination prior and post to Balloon Mitral valvotomy, which were recorded on ½ inch VHS vide tape for further off-line analysis.

TRANSTHORACIC ECHOCARDIOGRAPHY

Transthoracic M-mode, Two-dimensional, colour flow Doppler, pulsed and continuous wave Doppler and RT3DE (real time 3D echocardiogram) were performed in all the subjects, with Philips i.E. 33 ultrasound machine using X3-1 phased array transducer.

With the subject in left lateral decubitus position, continuous heart rate and single lead ECG on-line monitoring was done, and a complete TTE and RT3DE examination was performed following conventional criteria in multiple views. M-mode, 2D, Doppler and colour flow imaging of the mitral valve and related parameters were analyzed. Evaluation of LA size was done by M- mode and two-dimensional echocardiography. According to the American society of echocardiography criteria, LA dimension in M-mode by TTE represents the distance between the leading edge of the posterior aortic wall echo and leading edge of posterior LA wall echo at the level of aortic valve at end-systole. To determine the MVA by continuity equation left ventricular outflow tract diameter (LVOT), time velocity integrals (TVI) of LVOT and mitral valve measured. This equation was not used in aortic and mitral regurgitation.

To determine the MVO area by proximal isovelocity surface area (PISA) the following steps were used.1 Zoom the area of the mitral valve from apical four chamber view.2. Use color flow imaging of the mitral stenosis jet and upward shift of zero baseline for color map (30 to 40 cm/sec aliasing velocity) 3. Freeze color flow images in a cine loop and identify an optimal frame to measure radius (r) of PIZA in the left atrium .4.Determine the angle (α) between two mitral leaflets at the atrial surface and the PIZA formula used.

REAL TIME THREE DIMENSIONAL ECHOCARDIOGRAPHY

In each patient, RT3DE is performed immediately after 2D study using a Philips iE 33 ultrasound machine with an X3-1 probe. This probe is unique as it contains 3000 elements arranged in a rectangular format. Each transducer element is less than the size of the human hair. The foot print of the RT3DE probe is almost the same size as that of the 2D echocardiography probe.

RT3DE examination is performed from the same windows that are used for 2D echocardiography, namely parasternal long axis, parasternal short axis, apical, subcostal & suprasternal views .Hence the plane of examination and the views are exactly similar to that of 2D echocardiography.

Initially parasternal long axis view of mitral valve is obtained with routine 2D echo.. Then one can switch over from 2DE to 3DE so that 15^0 X 90^0 sector of the heart structures can be obtained. In case of mitral valve, apart from showing the anterior mitral leaflet and posterior mitral leaflet, its ventricular and atrial surface, the subchordal structures and papillary muscles can be clearly visualized by the 3D Echocardiography.

In the parasternal short axis view, apart from visualizing the fish mouth narrowest mitral valve orifice, one can rotate the picture and visualize the extent of commissural fusion, presence and extent of commissural splitting (medial, lateral or both commissures) can be analyzed post operatively. Any tear in the commissure can be visualized, as extension of splitting, perpendicular or oblique to the commissural line.

The RT3DE examination can also be done in the zoom mode to visualize the mitral valve or any other region of interest. In the zoom mode a 30^0 X 60^0 sector of the heart is visualized. This live 3DE can be performed from the standard echocardiography window using the standard 2DE windows as starting point.

The entire heart and surrounding structures can be interrogated and we can obtain a pyramidal shape datas set. The narrowest portion of pyramid being nearer to the transducer and the widest portion is in other end of transducer. The pyramid is about 80^0 X 90^0 in size. The 80^0 view is obtained as four datas set of 20^0 each from four cardiac cycles and the datas set are merged to get full pyramid. During full volume acquisition mode the patient should hold the breath during expiration and the datas are collected from four cardiac cycle.

The full volume data can be analyzed later by cutting it from different direction and also by slicing . The entire mitral valve, the orifice and the surface of mitral valve can be analyzed from the left atrial side or left ventricular side by post processing. This again helps us to obtain an enface view or surgeon's view of the mitral valve. The mitral valve orifice can be measured and the splitting of mitral valve, extension of commissural splitting and any tear in the leaflet can also be visualized.

The full volume acquisition can also be performed in the color Doppler mode. The size of pyramid is 60^0 X 90^0 and it is obtained from seven cardiac cycles with the patient holding the breath in expiration. The full volume datas set can be post processed and we can clearly visualize the stenotic or regurgitation jets. In case of mitral regurgitation, the area of the mitral regurgitation can be directly measured from the narrowest portion of the color Doppler jet.

RESULTS

Our study group comprised thirty five consecutive patients with rheumatic mitral valve stenosis. There were twenty one male and fourteen female with the mean age of 32.3 ± 9.2 yrs (range 22 to 45 years). Mitral stenosis was the predominant valvular lesion in all patients. In the pre-BMV period, twenty one patients had associated mild mitral regurgitation, whereas two patients had associated mild aortic regurgitation. None of the patients showed aortic stenosis. Regarding the analysis of the tricuspid valve, none of the patients showed tricuspid stenosis, but 27 showed tricuspid regurgitation. Systolic and diastolic left ventricular diameters from the parasternal approach were 43±5and 34±8mm. All patients were in normal sinus rhythm.

Regarding the BMV procedure, the size of the balloon was selected according to the body surface index. The mean body surface was 1.73±0.18, the body mass surface index 27.31 ± 5.06 and accordingly the mean INOUE balloon used was 28.1 ± 1.20. No deep anesthesia was used for the BMV.

Their functional capacities were ranged between class II – class III according to New York Heart Association classification (NYHA). Left atrium diameter was 45.1 ± 3.2 mm. Mitral valve orifice areas were 0.7 ± 0.17cm^2. Mitral valve pressure halftime varied between 325 ± 60ms. Mitral valve peak transvalvular gradient 25.0 ± 8.18 mmHg. Mitral valve mean gradient 16.1± 5.36 mmHg.

EF slope ranged 22.2 ± 2.27mm/sec. LVOT diameter was 1.8 ± 1 cm. Right ventricular diastolic diameter was 25 ± 2 mm. Aortic end systolic diameters 25± 3

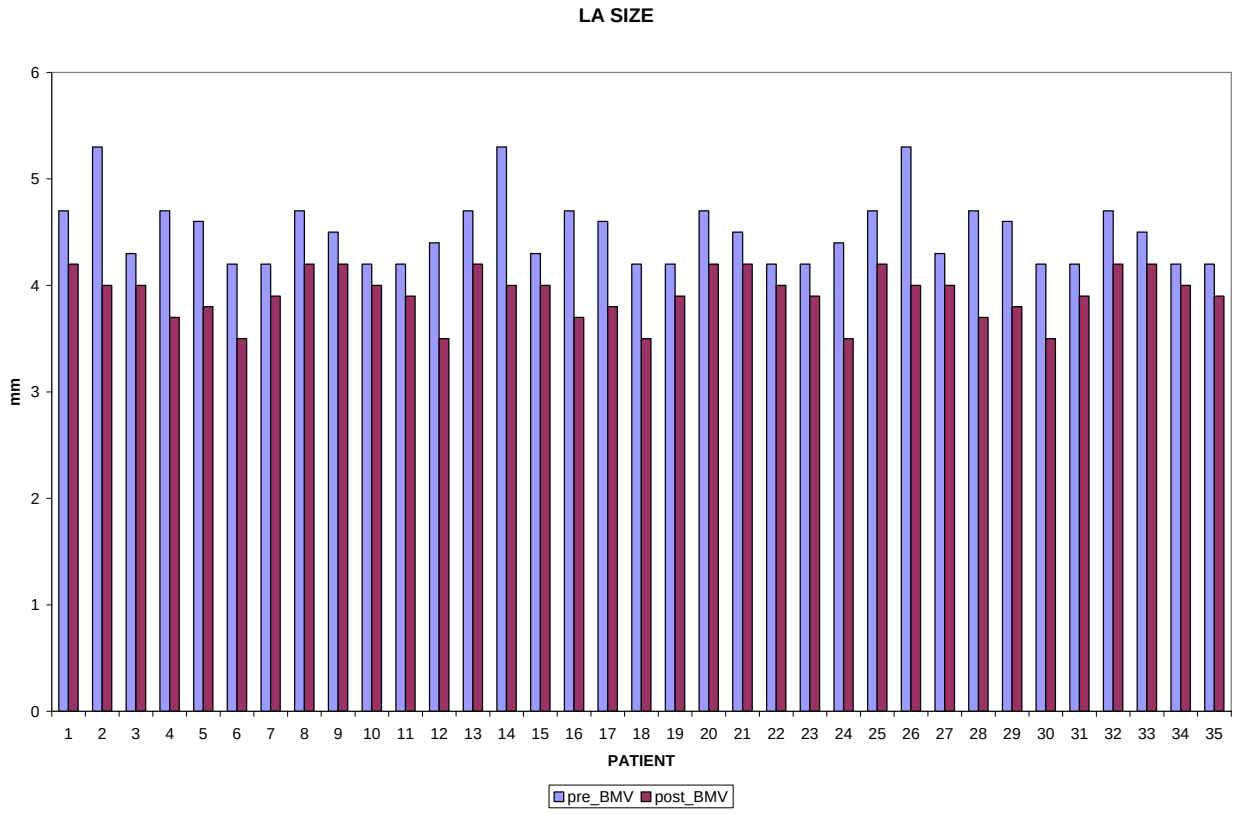
mm. The pulmonary artery systolic pressure 59.8 ± 18.61mmHg. Mean Pulmonary artery pressure 39 ± 13.15mmHg. Left atrial mean pressure 24.2 ± 4.96mmHgG. Right ventricle systolic pressure was 59.8 ± 18.6mmHg. Right atrial mean pressure 7.3 ± 1.4mmHg. One patient under went previous balloon mitral valvotomy. Twenty one patients were noted to have mild mitral regurgitation. The Wilkins score was 3± 2.

After the Balloon mitral valvotomy their functional capacity improved to NYHA class I. Left atrial diameter decreased to 39.2 ± 2.4mm. Mitral valve orifice increased to 1.45±0.19cm^2. MV PHT decreased to 150 ± 20ms. Mitral valve peak gradient decreased to 11.8 ± 2.95 mmHg. Mitral valve mean gradient reduced to 7.3 ± 2.14 mmHg. RV diastolic diameter was reduced in size 15 ± 2mm. The mean pulmonary artery pressure decreased to 23.2 ± 9.38mmHg. The left arterial mean pressure considerably decreased to 10.5 ± 3.09 mmHg. The right ventricular systolic pressure decreased to 36.0 ± 11.3 mmHg.

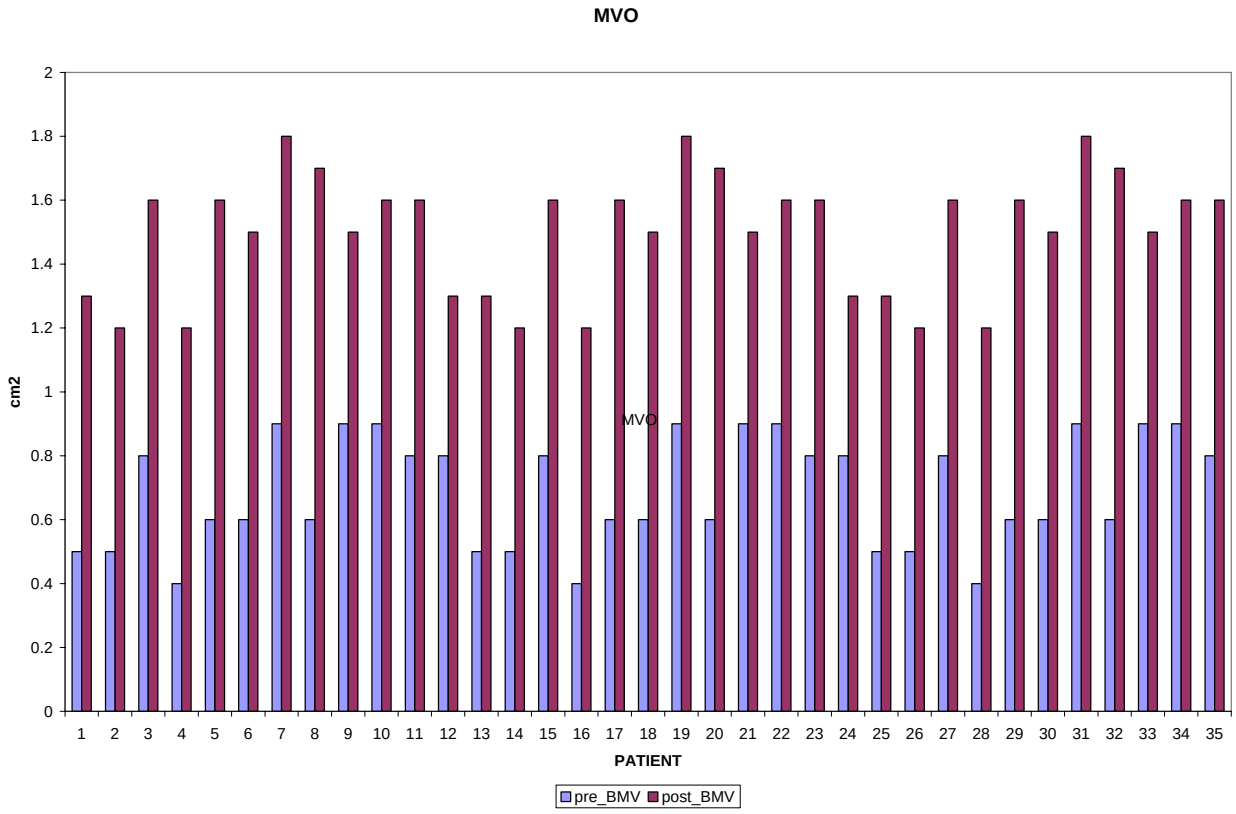
The Real Time 3D Echocardiogram showed well delineated commissural splitting and atrial puncture site. It also clearly visualized rupture of anterior mitral leaflet. Out of Thirty five patients, ten patients had bilateral commissural splitting. Eighteen patients showed unilateral splitting of commissure. RT3DE was able to identify asymmetrical splitting of commissures in seven patients who had mild to moderate mitral regurgitation. Three patients had rupture of anterior mitral leaflet in addition to asymmetrical splitting of commissure which transthoracic Echocardiogram had failed to visualize. One Patient had two atrial septal puncture sites which were clearly visualized by RT3DE.

Parameters	Pre-BMV	Post-BMV	P-value
NYHA	Class II-III	Class I	<0.05
Left atrium diameter (mm)	45.1±3.2	39.2±2.4	<0.05
Mitral valve orifice (cm^2)	0.7±0.17	1.45±0.19	<0.05
Mitral valve peak gradient (mmHg)	25.0±8.18	11.8±2.95	<0.05
Mitral valve mean gradient (mmHg)	16.1±5.36	7.3±2.14	<0.05
Pulmonary artery systolic pressure (mmHg)	59.8±18.61	36.0±11.13	<0.05
Mean pulmonary artery pressure (mmHg)	39.0±13.15	23.2±9.38	<0.05
Left atrial mean pressure (mmHg)	24.2±4.96	10.5±3.09	<0.05
RA mean pressure (mmHg)	7.3±1.47	6.4±0.96	<0.05
RV systolic pressure (mmHg)	59.8±18.61	36.0±11.13	<0.05
MVO Continuity equation(cm^2)	0.65 ±0.17	1.5 ±0.18	<0.05
MVO (cm^2) RT3DE	0.7±0.17	1.46±0.17	<0.05

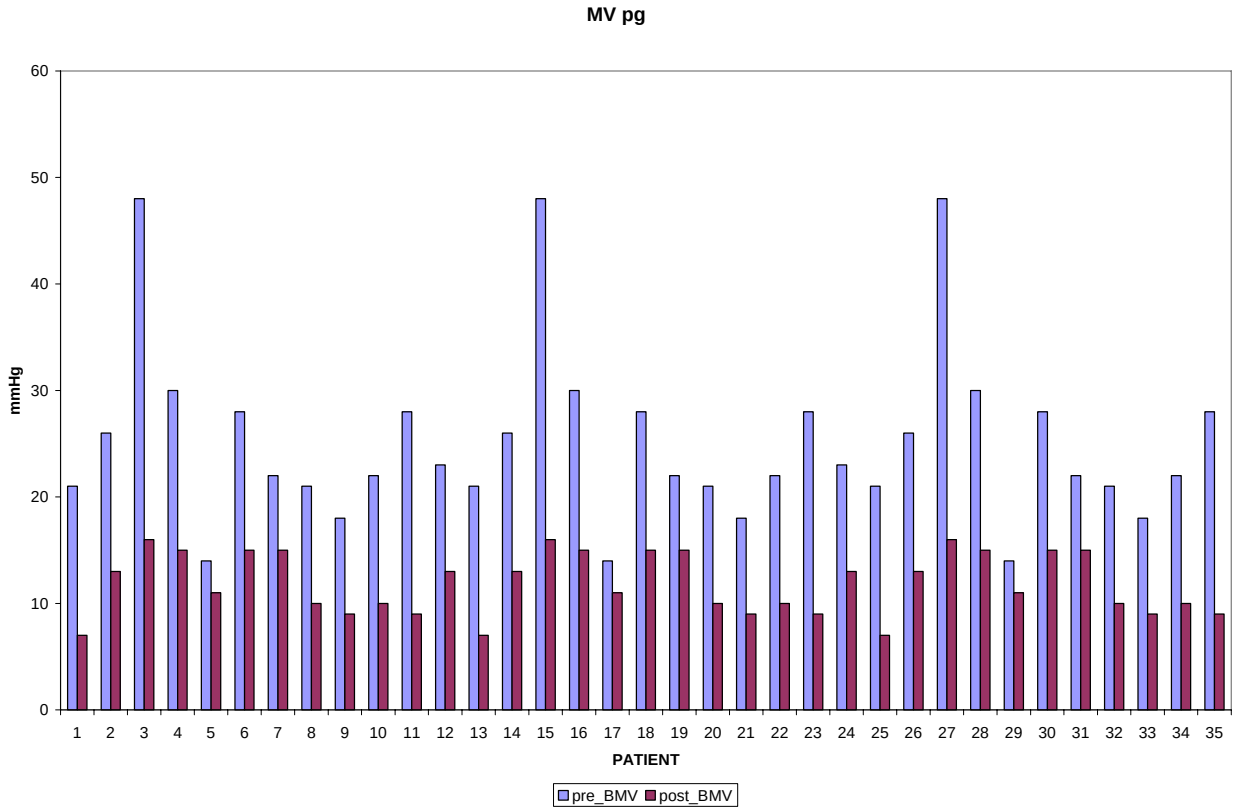
Table 3: Echocardiographic and haemodynamic characters in pre and post BMV



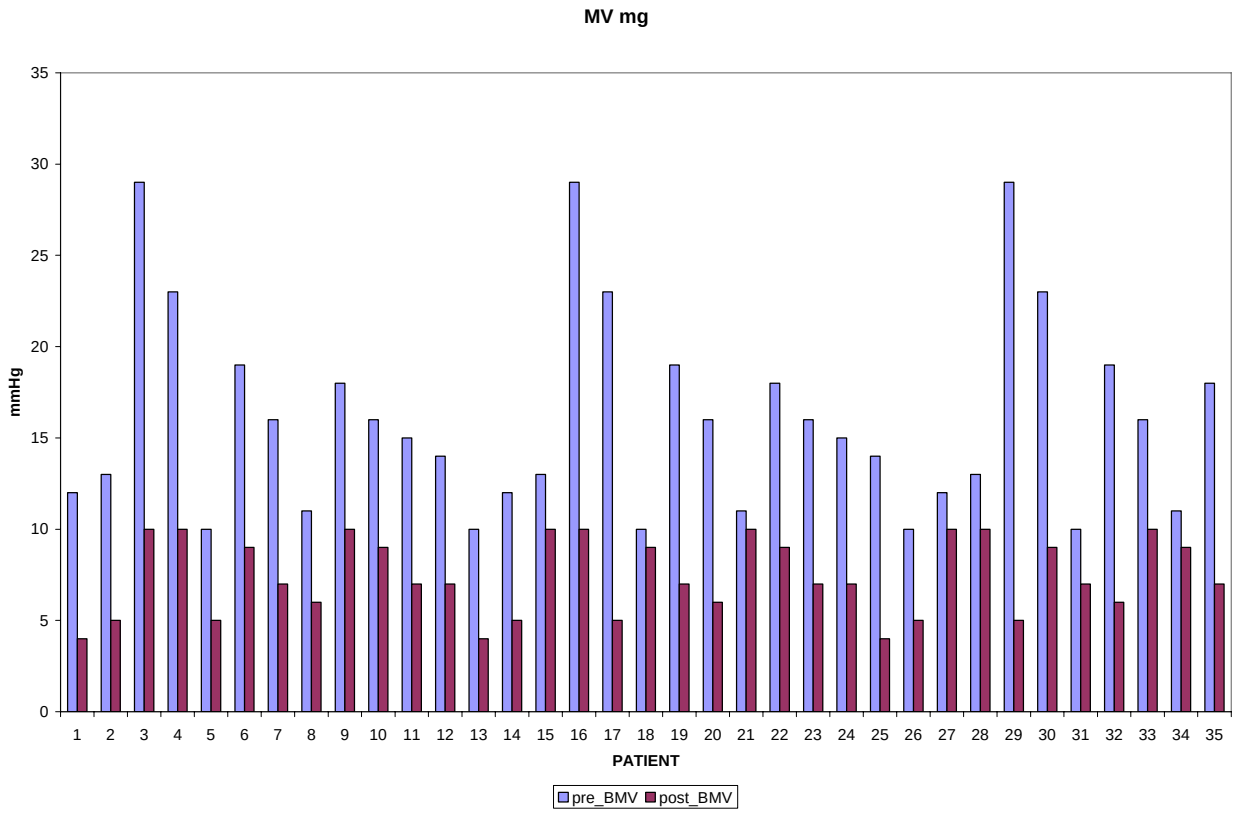
Bar diagram1: Left atrial size in pre and post BMV



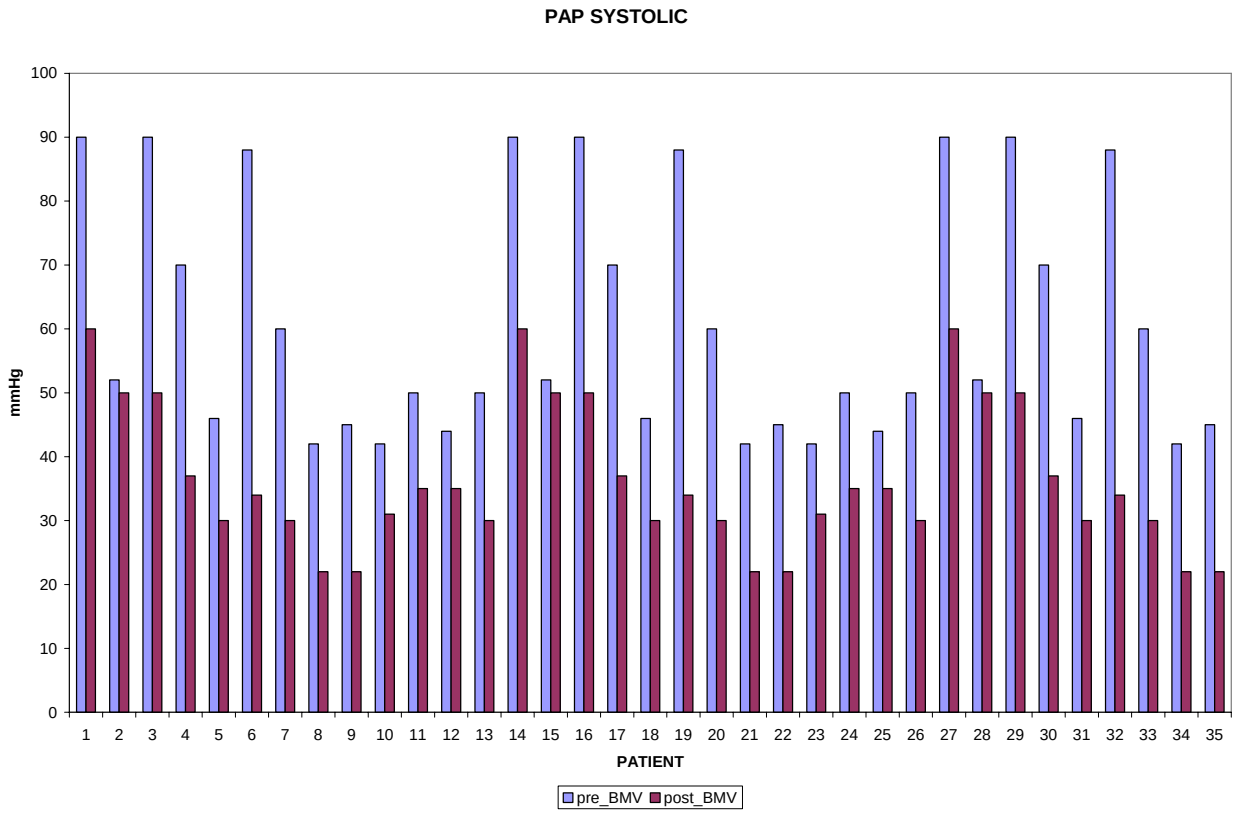
Bar diagram2: Mitral valve orifice in cm^2 size in pre and post BMV



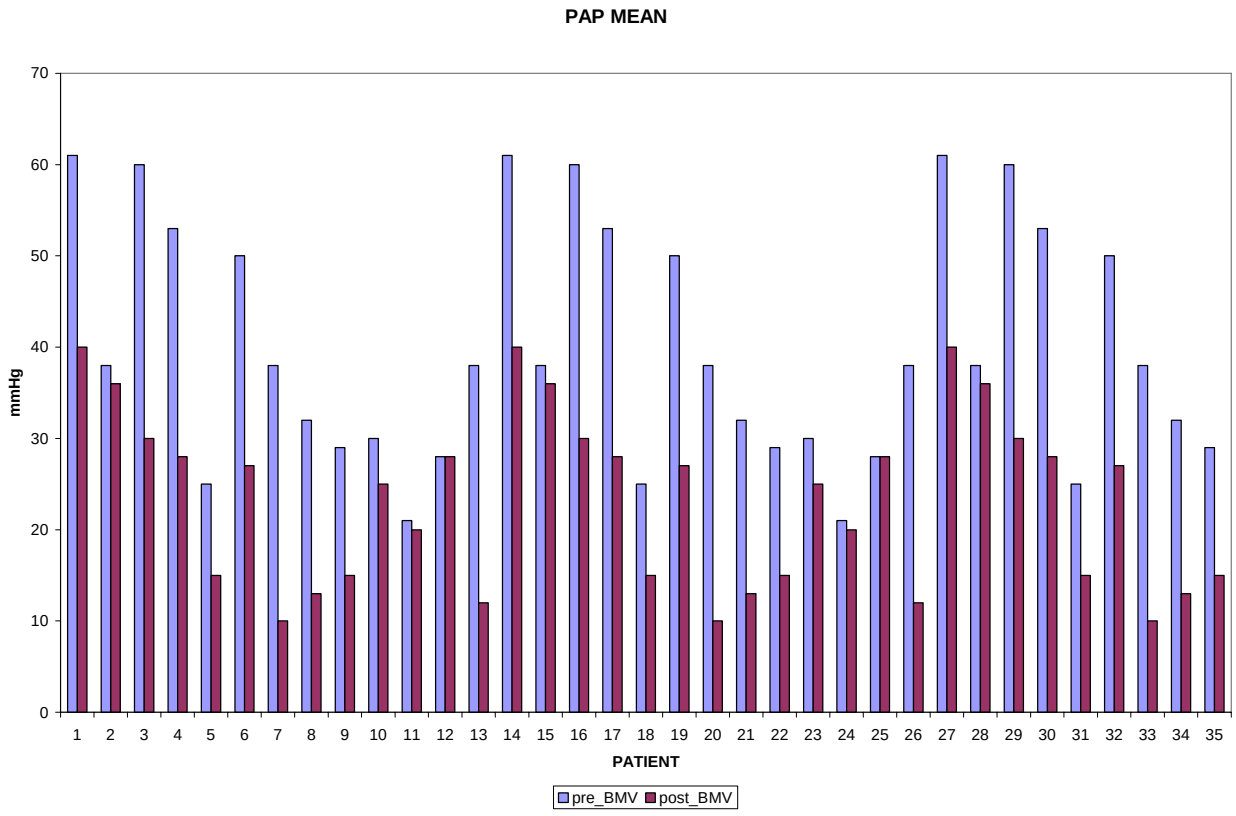
Bar diagram 3: Trans mitral valve peak gradient in pre and post BMV



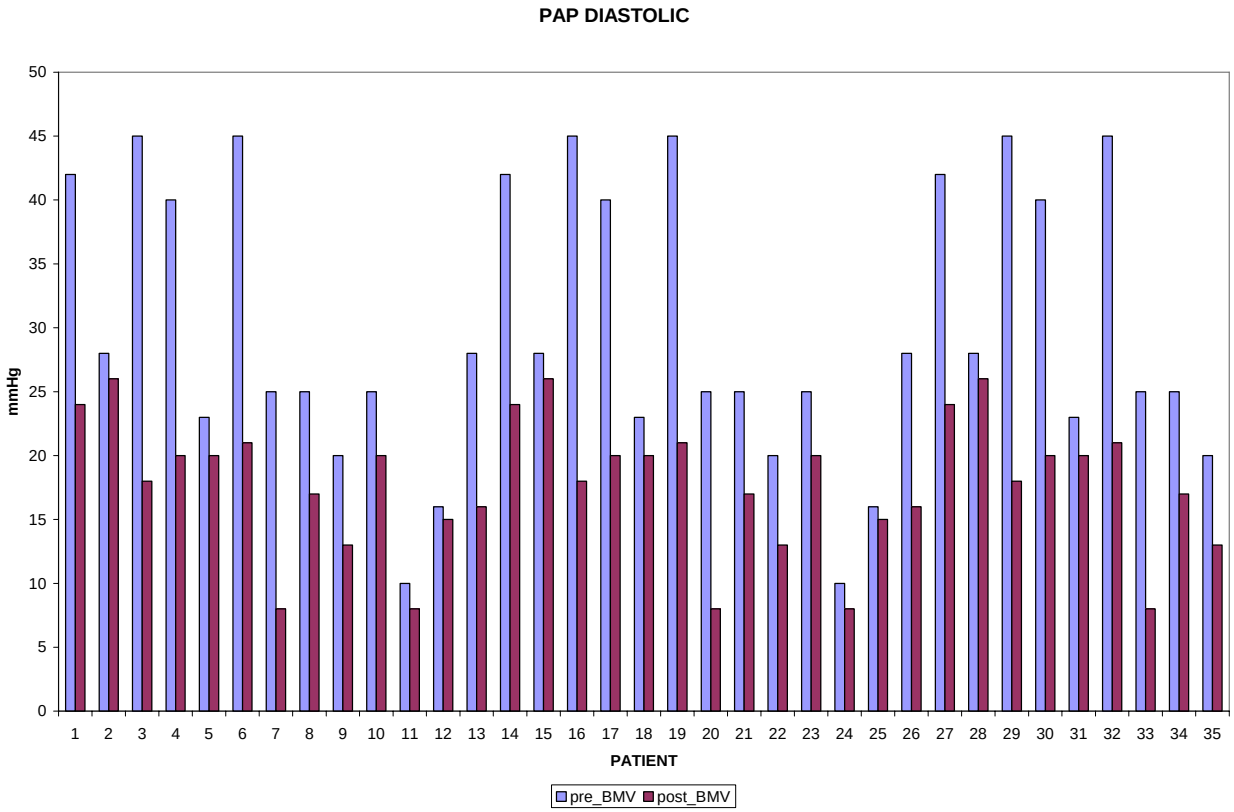
Bar diagram 4: Trans mitral valve mean gradient in pre and post BMV



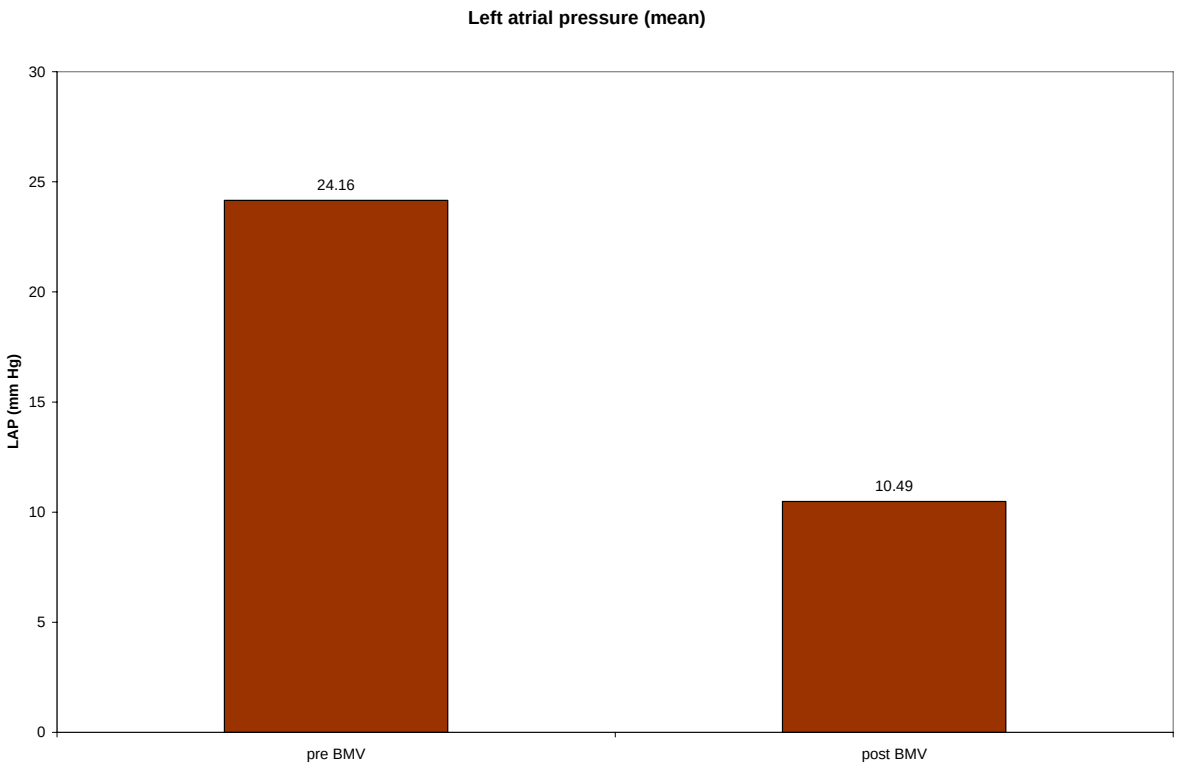
Bar diagram 5: Systolic pulmonary artery pressure in pre and post BMV



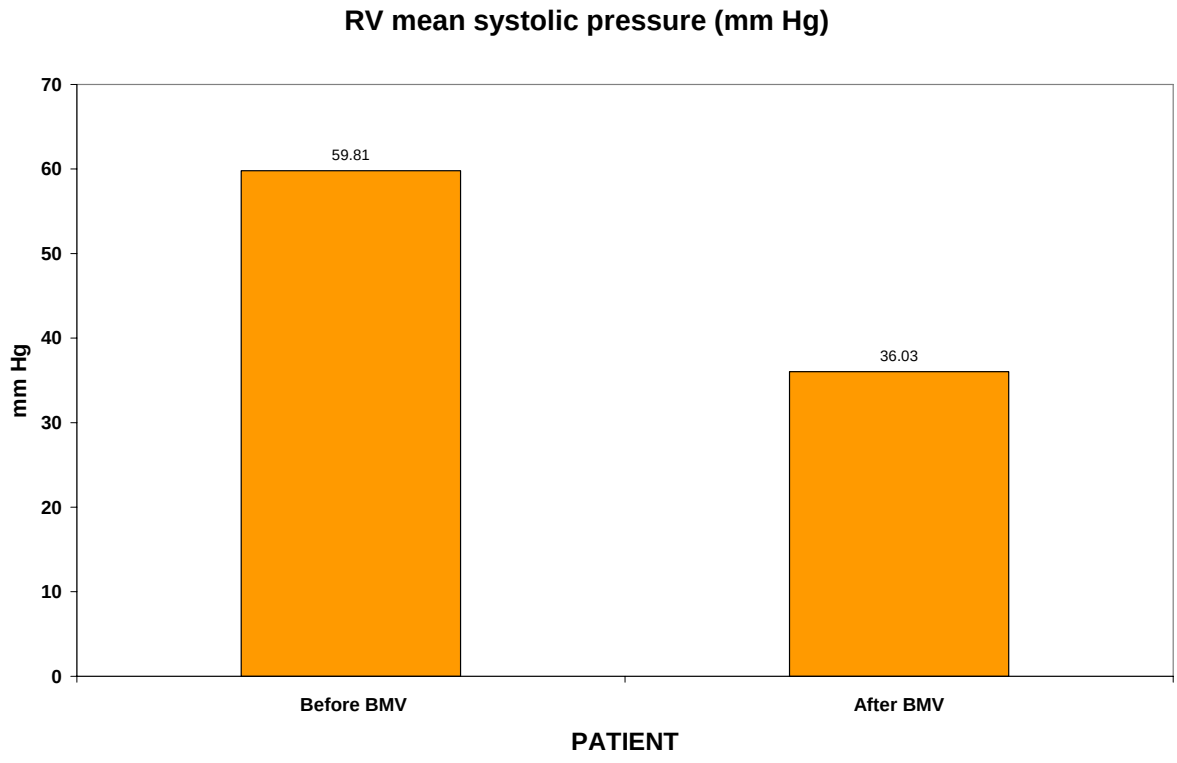
Bar diagram 6: Mean pulmonary artery pressure in pre and post BMV



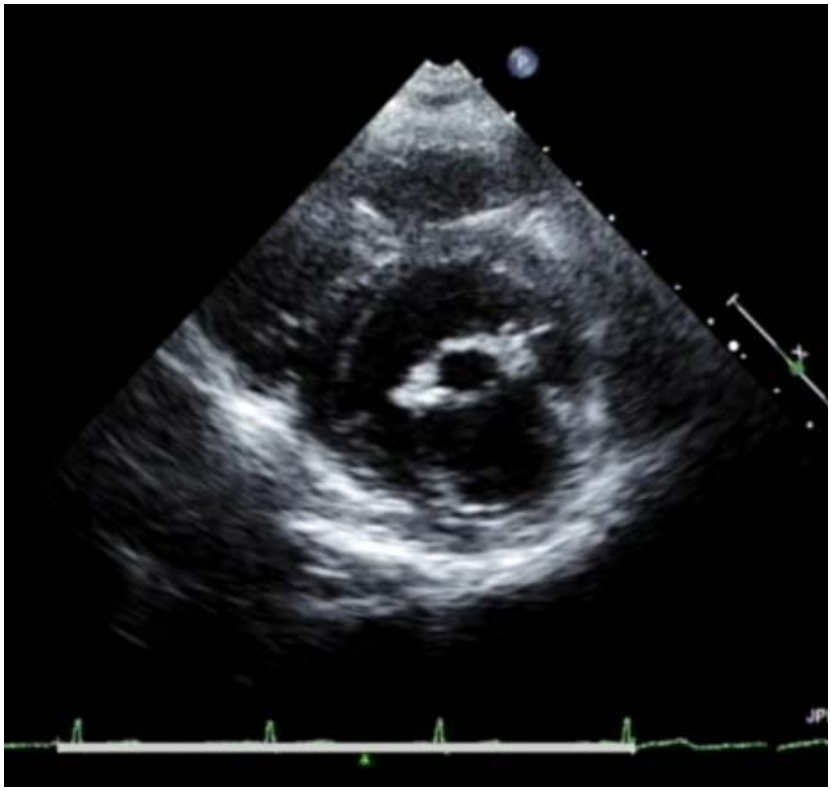
Bar diagram 7: pulmonary artery diastolic pressure in pre and post BMV



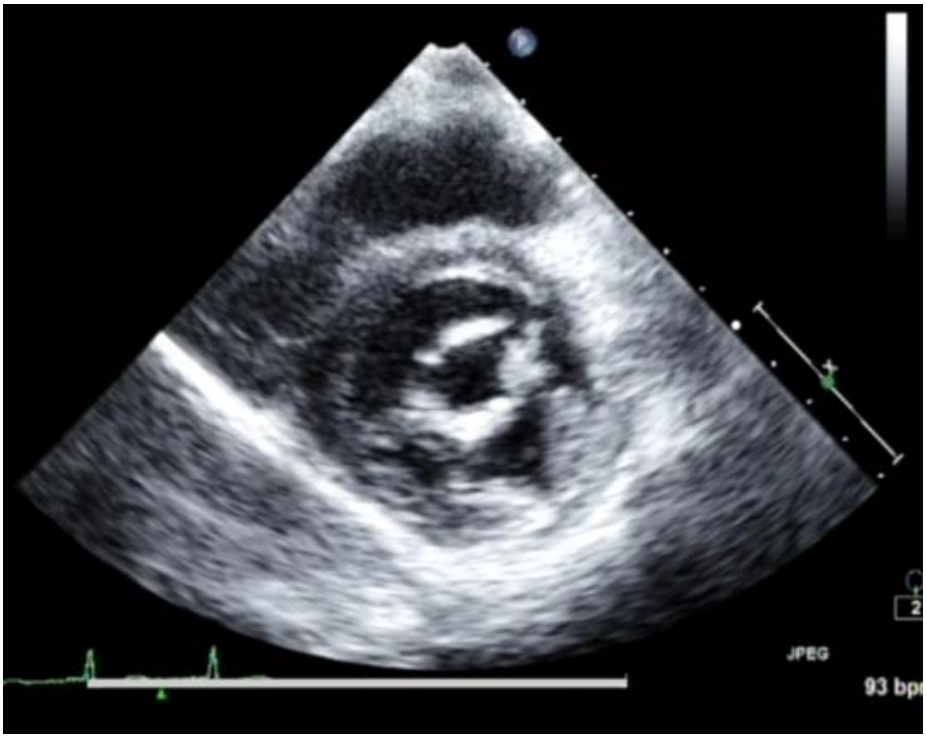
Bar chart 1: Left atrial mean pressure in pre and post BMV



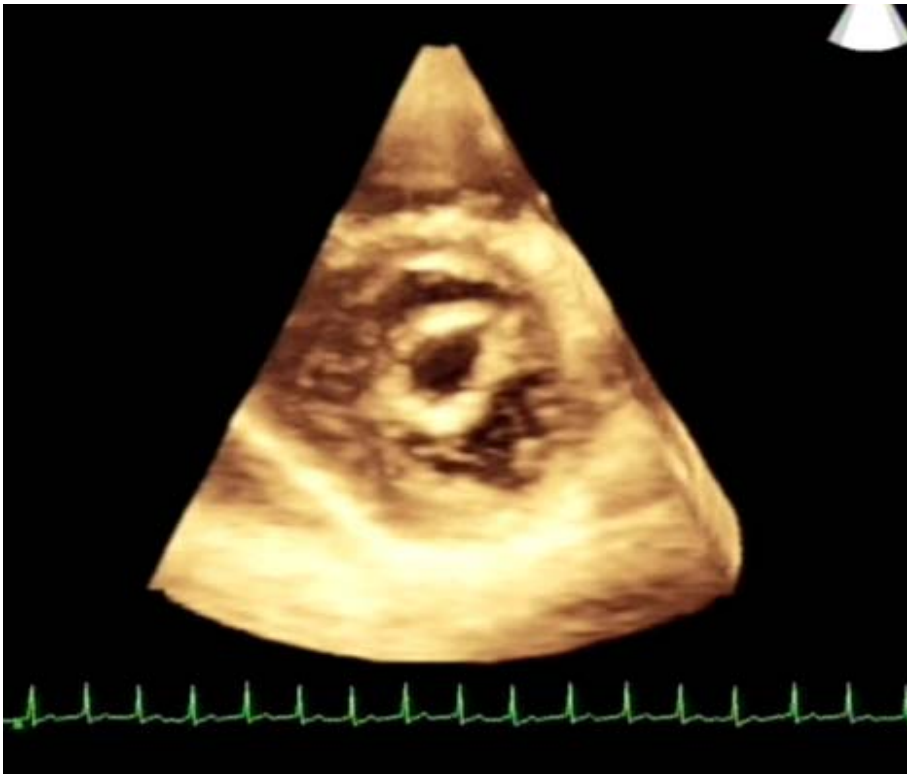
Bar chart 2: Right ventricular systolic pressure in pre and post BMV

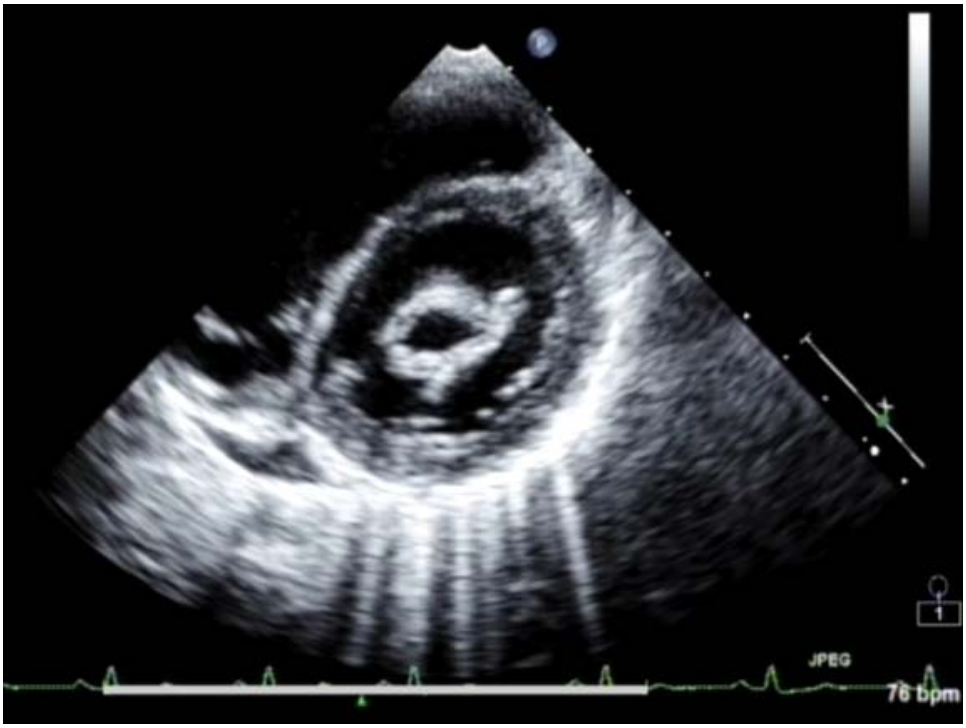


2DE & 3DE Pictures show bilateral commissural fusion – pre BMV

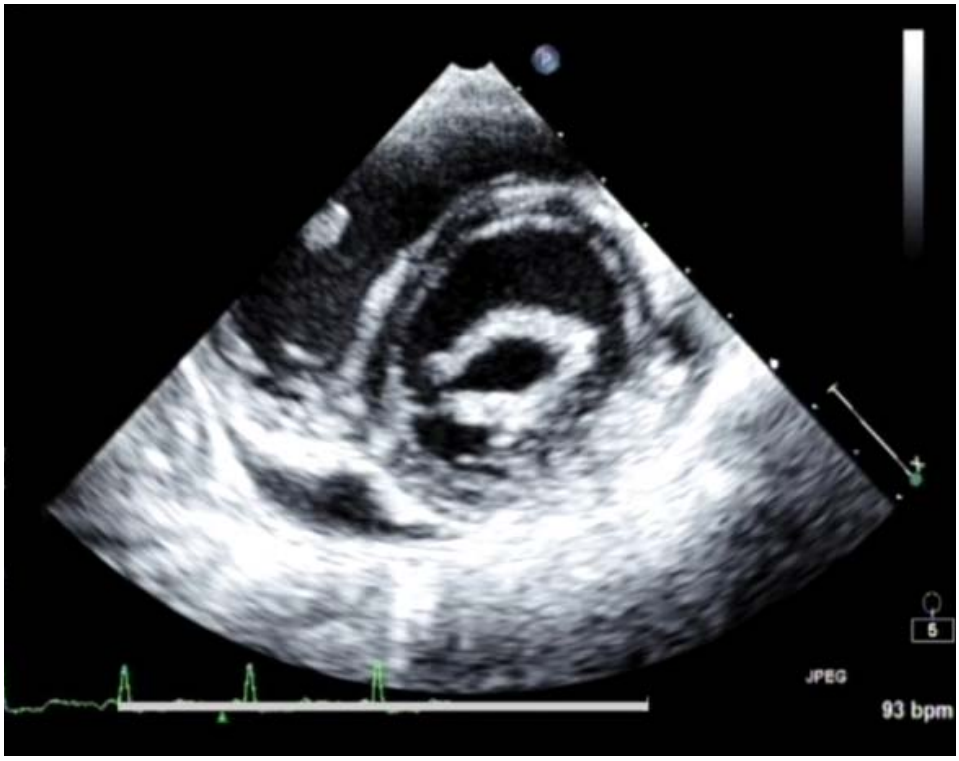


2DE & 3DE Pictures show unilateral commissural splitting –post BMV



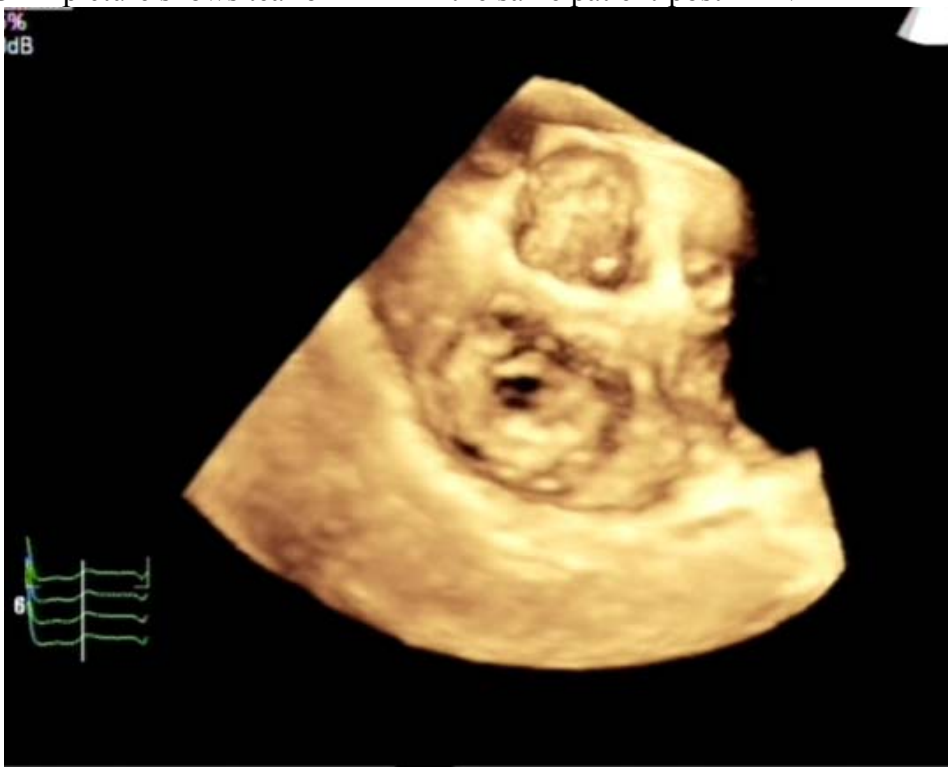


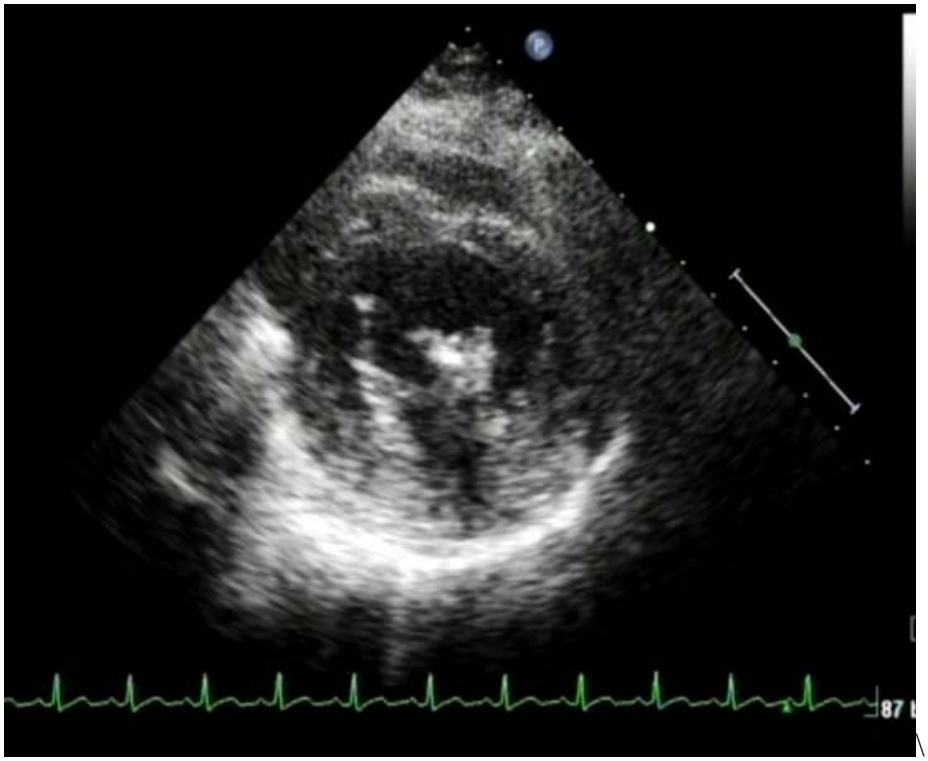
2DE & 3DE pictures show bilateral commissural fusion –pre BMV



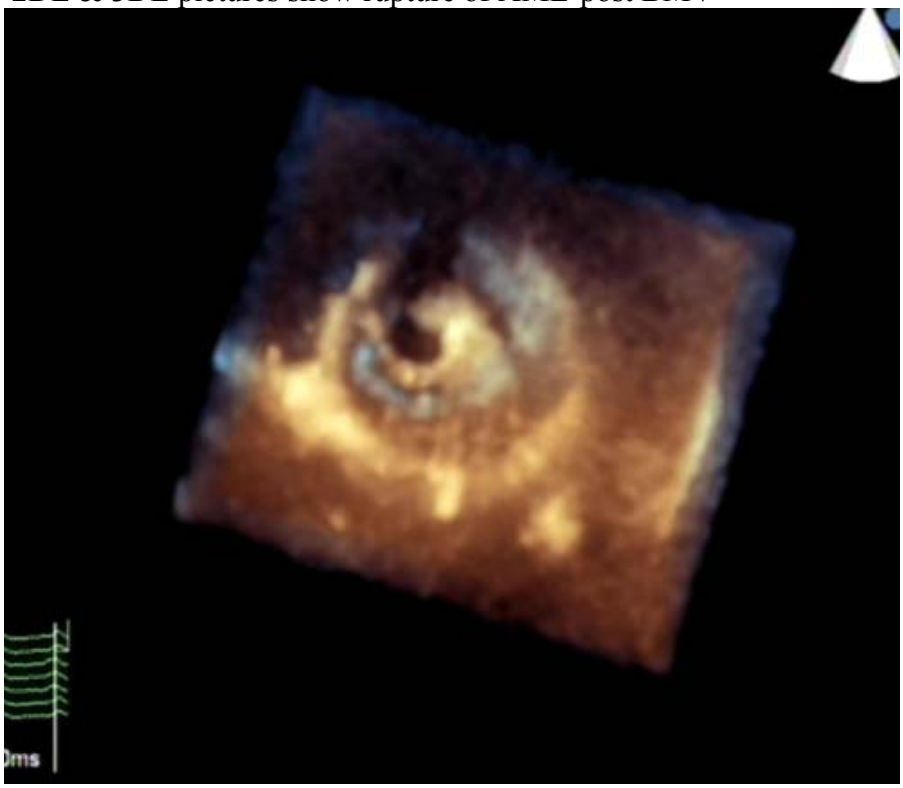
2DE picture shows unilateral splitting of medial commissure-post BMV

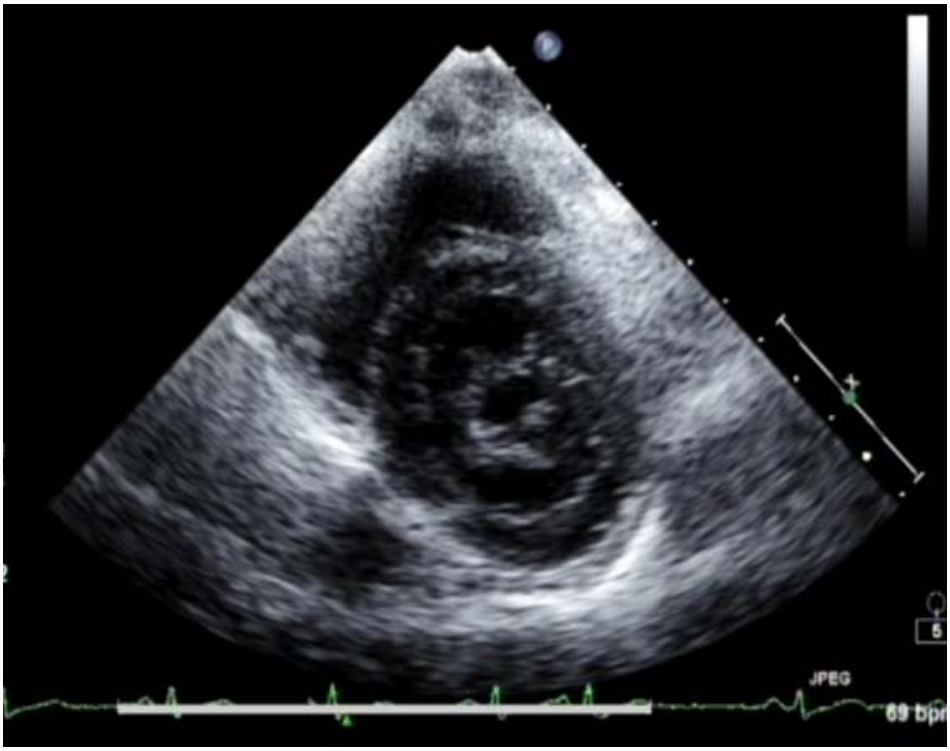
3DE picture shows tear of AML in the same patient-post BMV



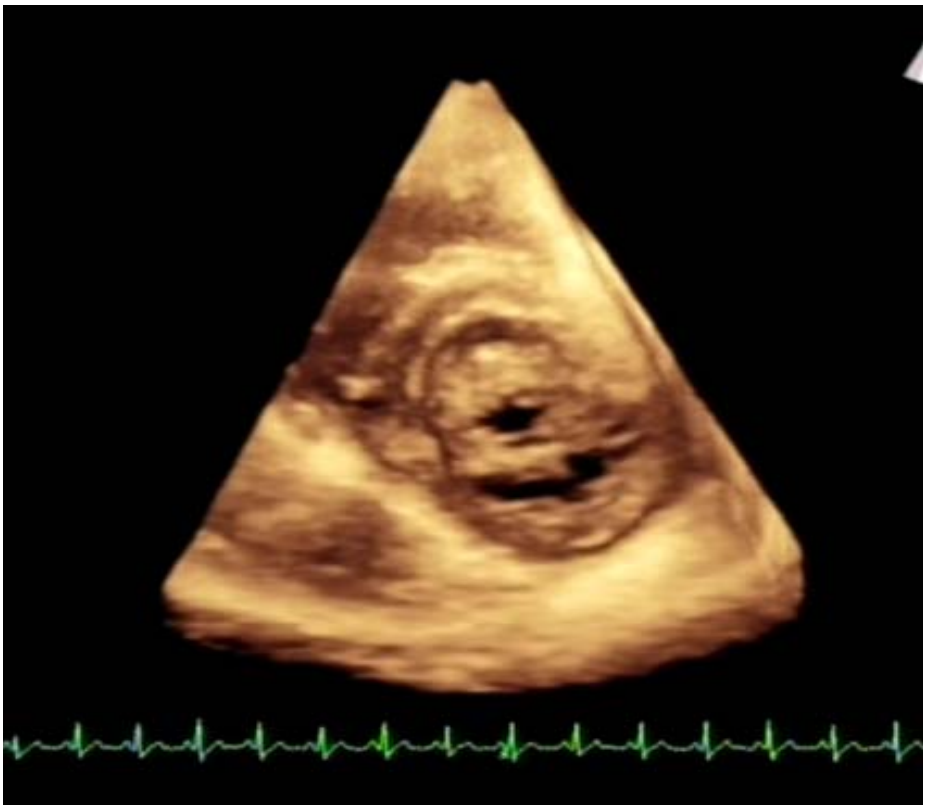


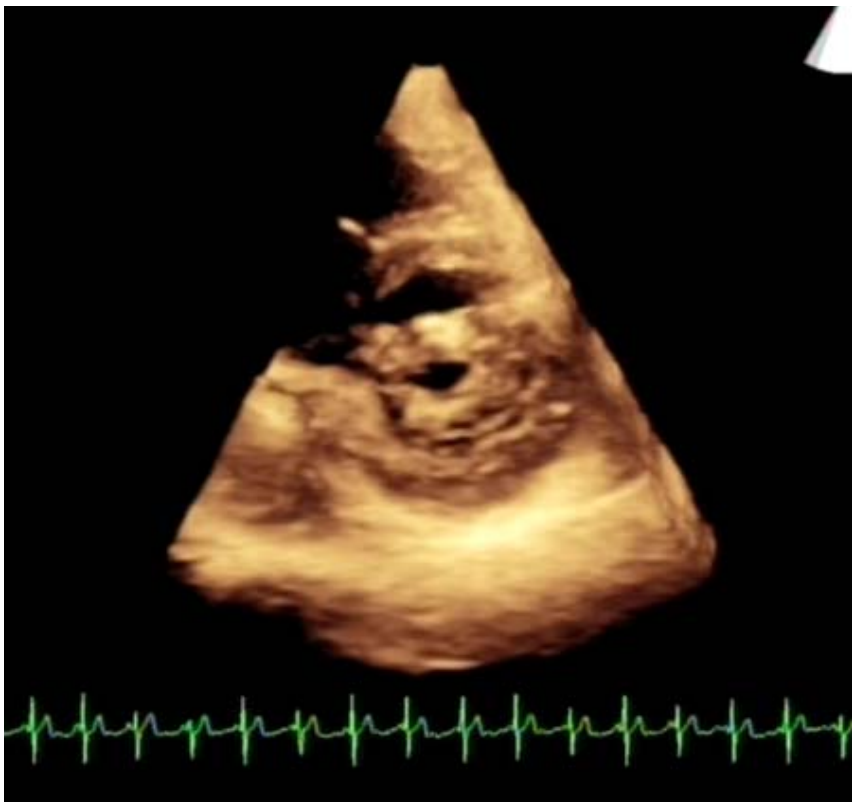
2DE & 3DE pictures show rupture of AML-post BMV



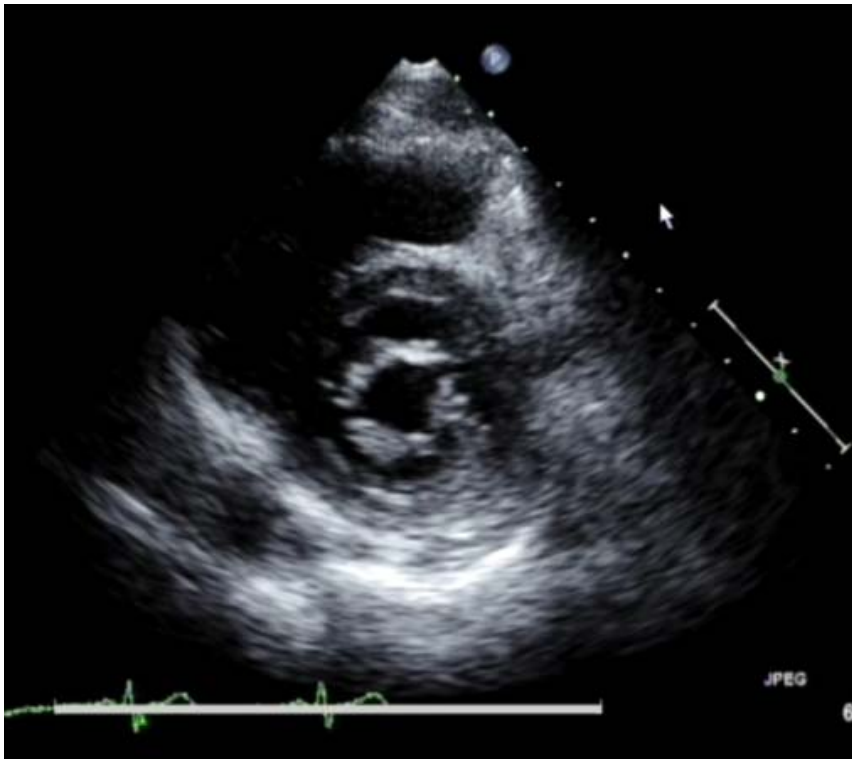


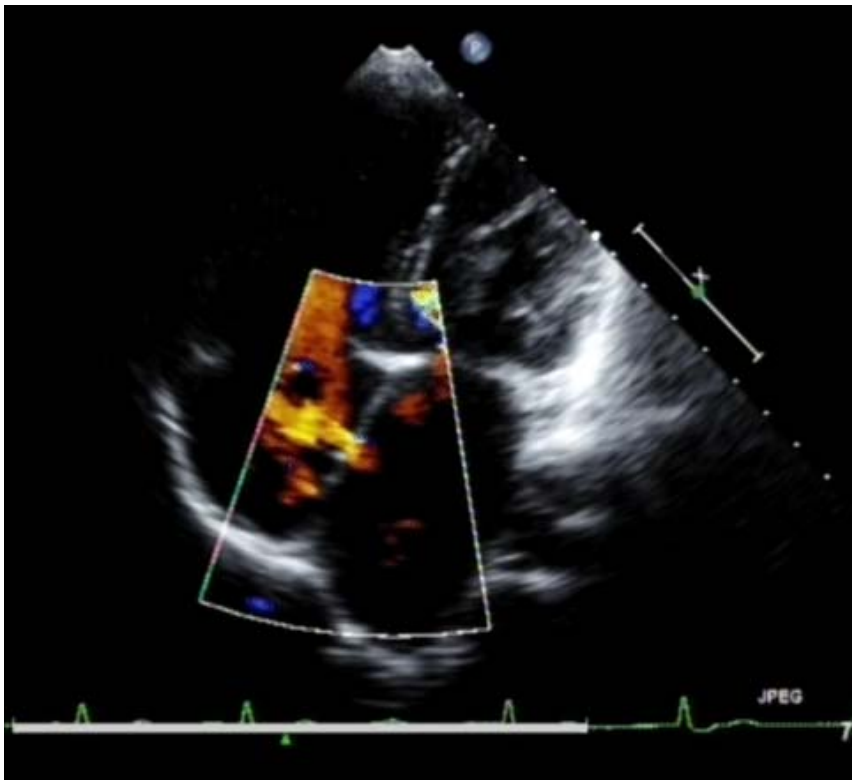
2DE & 3DE pictures show bilateral commissural fusion-pre BMV



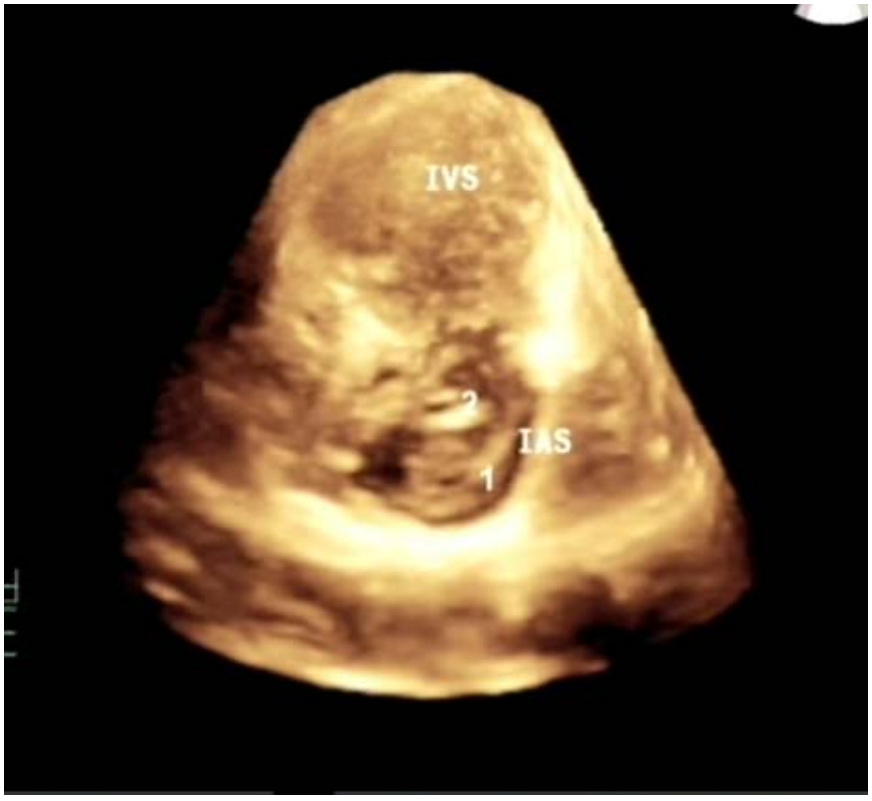


2DE & 3DE pictures show bilateral commissural splitting –post BMV





2DE & 3DE pictures show two atrial puncture sites-post BMV



DISCUSSION

Percutaneous BMV is a safe, effective, less invasive alternative to surgery for selected patients with mitral stenosis. It has been shown to convey a similar improvement in

hemodynamics, valve area and symptoms for up to 2 years after the procedure as compared with open surgical commissurotomy[24].

It is, however, not without morbidity, the most serious being cardiac perforation, systemic emboli and the development of mitral regurgitation[25] . These potentially lethal complications can be minimized with the use of echocardiography. Doppler echocardiography has a clear and well-established role in evaluating patients with mitral stenosis who undergo BMV.

Transthoracic echocardiography is a standard screening tool that is used to assess the mitral valve and submitral apparatus in patients who are potential candidates for this procedure. It has also been used to monitor patients during BMV. Immediately before BMV, Tranthoracic echocardiography used to clearly visualize the left atrium, left atrial appendage and interatrial septum for the presence of thrombi, which are a potential source for systemic embolization during the procedure.

During valvuloplasty Tranthoracic echocardiography has been shown to be an invaluable aid in guiding the transseptal puncture by visualizing the “Tenting” of the interatrial septum by the Brockenbrough needle.

Tranthoracic echocardiography is also useful in guiding the balloon catheter across the mitral valve and obtaining a quick and accurate assessment of the mitral valve area and the amount of mitral regurgitation.

After valvuloplasty Tranthoracic echocardiography can assess the adequacy of the procedure and identify the presence, exact location and size of iatrogenic atrial septal defects.

In this study we have shown the advantages of obtaining three-dimensional echocardiographic reconstructions during BMV. This technique offers the ability to view the mitral valve from any cut-plane of the three-dimensional data set. By viewing the mitral valve from the perspective of looking up from the left ventricle, the mitral leaflets, commissures and mitral annulus were easily visualized en-face.

The two dimensional Tranthoracic echocardiography can accurately visualize a larger mitral valve orifice or an increase in the amount of mitral regurgitation. However, it is often difficult and potentially inaccurate to mentally reconstruct a three-dimensional image from the two-dimensional echocardiographic images. Therefore, by comparing the initial three-dimensional reconstruction to the one obtained after the procedure, the extent of commissural

splitting was easily evaluated and was shown to be related to the extent of improvement in mitral valve area with BMV.

When the development of worsening of mitral insufficiency complicated BMV, leaflet tears were visualized in three patients. What three-dimensional reconstruction provides that is not obtainable from two-dimensional echocardiography is the mechanism by which valve area increases, as well as the detection of leaflet tear.

The three-dimensional echocardiographic reconstructions correlate well with what is seen on pathologic specimens and direct visual inspection of the valves of patients who underwent .MV. Hogan et al[27]. analyzed pathologic specimens of mitral valves in 11 patients who underwent BMV and found that fracture of the commissural fusion was the fundamental mechanism for the success of the procedure. This was also described by Inoue et al[28]. who were the first to describe the anatomic mechanism of successful BMV in patients undergoing open commissurotomy. Tears of the mitral valve leaflet were shown to be responsible for the development of mitral regurgitation secondary to balloon valvuloplasty in three-fifths of mitral valves studied pathologically. BMV has become the procedure of choice in symptomatic patients when the stenotic mitral valve is not heavily calcified and mitral regurgitation is not significant because it is cost effective and safe. This technique may also be used in patients with less favourable anatomic features, particularly in patients who are considered to be at high surgical risk[29], such as pregnant women[30], very elderly patients, patients with associated severe ischaemic heart disease or associated severe pulmonary, renal, or malignant diseases. The results of BMV are equivalent to those of surgical, open commissurotomy and both give better results than closed commissurotomy[31].

Patients with Rheumatic mitral valve stenosis who require an intervention can be easily identified using non-invasive techniques and the results can be predicted by a careful pre- BMV Doppler echocardiographic evaluation. Before the BMV, the pressure gradient, the valvular area, and the severity of valvular regurgitation, can be used to evaluate patients reliably. Prior to BMV, Doppler echocardiographic estimation of MVA correlates well with invasive estimation.

Immediately following BMV, the PHT method has been shown to have a poor agreement with invasive data[32]. There are various reasons for this inaccuracy including: (1) the development of an atrial septal defect in many patients after BMV[33], and (2) the PHT method assumes that the left atrial and left ventricular compliances remain stable[34]; this assumption is not valid in the immediate period following BMV because rapid changes in the left atrial pressure and left ventricular filling occur in this setting, affecting the compliance of

both the left atrium and ventricle.

Compared to the PHT method, planimetry (2D or 3D) is not as dependent on haemodynamic variables (heart rate, cardiac index, cardiac rhythm, left ventricular systolic and diastolic dysfunction, left ventricular and atrium compliance, left ventricular hypertrophy and concomitant valvular disease) [35]. Accordingly, planimetry of MVA should be more accurate in the setting of PMV.

Planimetry of mitral valve orifice using 2D echo is a valid method but has its own set of limitations, especially following valvuloplasty when the mitral orifice becomes irregular and technically difficult to trace, particularly if calcium is present.

3D echo allows a different and superior evaluation of the mitral valve apparatus, improving the ability to obtain an accurate measurement of the MVA[36]. Restriction of the tips and chordae, during the evolution of the rheumatic mitral valve disease, effectively converts the mitral valve apparatus into a funnel with its restrictive mitral valve orifice being at the tips of the leaflets. Due to the variable geometry of the stenotic mitral valve orifice, correct plane orientation frequently becomes difficult.

Minor changes in depth and angle of the ultrasound beam leads to an overestimation of the MVA by anywhere from 63% to 88%[37]. 3D echo has already been shown to be useful to optimise the results and prevent the development of significant mitral regurgitation during balloon mitral valvuloplasty[38]. The use of the new transthoracic 3D matrix array probe that allows on-line 3D rendering, allows fast visualization of the mitral valve apparatus and the acquisition of en face views of the mitral valve from which the accurate measurements of the mitral valve area can be made. This image modality should be routinely used to both monitor the mitral BMV and obtain accurate MVA measurements.

In this study, RT3D was the most accurate echocardiographic technique for measuring MVA. Compared with PHT and 2D echo planimetry, RT3D echo had the best agreement when compared to the invasively derived MVA. Not only did this occur in the pre-BMV period but also in the post-BMV period.

Thus, our results show that RT3D is an accurate and practical non-invasive tool for measuring MVA in all clinical situations, including the immediate post-BMV period. Importantly, since manipulation of the RT3D echo probe is similar to other clinically used transthoracic 2D probes, sonographers do not need a long training period to be versatile with RT3D image acquisition[39].

We need to know, that although 3D echo provides a more accurate evaluation of the anatomy of the mitral valve, as with 2D echo, it is importantly influenced by the quality of the acoustic window. Needless to say that although the new equipment provides better resolution and image quality, a bad acoustic window will lead to a poor analysis of the patient.

LIMITATIONS

There are several possible limitations of three-dimensional volume-rendered echocardiographic reconstructions. This technique is extremely sensitive to proper gain settings from the two-dimensional data acquisition as well as to the level of threshold chosen (which defines the interface between tissue and blood) during the three-dimensional reconstruction. An inappropriate setting of either modality can result in ultrasonographic dropout, which would distort the accurate visualization of the valve anatomy.

During data acquisition three-dimensional echocardiographic reconstructions are also very sensitive to both patient and operator movement, either of which can distort the image. Also, the time required for data acquisition and reconstruction, although improving, is still too long for the three-dimensional data to be obtained between balloon inflations.

Measuring the mitral valve area by pressure half-time after BMV can be inaccurate secondary to changes in left atrial and ventricular compliance as well as the creation of an atrial septal defect[40]. The three-dimensional reconstruction allows us to measure the mitral valve area by planimetry by choosing the cut-plane with the smallest mitral valve orifice. Although three-dimensional planimetry could be affected by gain settings and post processing, we found these results to be similar to the mitral valve area measured by pressure half-time, and we believe that this merits further investigation with a larger number of patients.

CONCLUSIONS

1. Three-dimensional echocardiographic reconstruction of the mitral valve obtained by transthoracic echocardiography during BMV is a new, noninvasive imaging technique that can more accurately visualize the mechanisms of successful BMV, as well as some of its complications.

2. This can potentially be used to further guide and optimize the results of BMV by visualizing the extent of commissural splitting so that a maximal mitral valve area can be obtained safely. It may also help to prevent the development of significant mitral regurgitation during the procedure. Visualizing a small tear of the mitral valve leaflet associated with only minimal valvular regurgitation may prevent another balloon inflation that may worsen the tear and create more significant mitral regurgitation.

3. Further improvements in the hardware and software of this echocardiographic system are needed to test this hypothesis so that larger studies transthoracic RT3DE is a feasible and accurate technique for measuring MVA in patients with Rheumatic mitral valve stenosis compared to the PHT method and 2D echo planimetry, RT3DE results have the best agreement with the invasively determined MVA, particularly in the immediate post-BMV period, where PHT is inaccurate.

BIBLIOGRAPHY

1. Edwards WD. Anatomy of the cardiovascular system: Clinical medicine: Vol 6. Philadelphia: Harper & Row; 1984:1-24.

2. Edwards WD. Applied anatomy of the heart. In: Giuliani ER, Fuster V, Gersh BJ, et al, eds. Cardiology fundamental and practice,2d ed:Vol 1. St louis; Mosby – Year Book; 1991: 47-112.

3. Edwards WD. Applied anatomy of the heart. In: Giuliani ER, Fuster V, Gersh BJ, et al, eds. Cardiology fundamental and practice,2d ed:Vol 1. St louis; Mosby – Year Book; 1991: 47-112.

4. Edwards WD. Anatomy of the cardiovascular system: Clinical medicine: Vol 6. Philadelphia: Harper & Row; 1984:1-24.

5. Edwards WD. Applied anatomy of the heart. In: Giuliani ER, Fuster V, Gersh BJ, et al, eds. Cardiology fundamental and practice,2d ed:Vol 1. St louis; Mosby – Year Book; 1991: 47-112.

6. Edwards WD. Cardiac anatomy and examination of cardiac specimens. In: Emmanouilides G, Reimenschneider T, allen H, Gutgesell H, eds. Moss & Adam's Heart Disease in infants, Children and adolescents, 5th ed. Baltimore: Williams & Wilkins ; 1995: 70-105.

7. Inoue K, OwakiT, Nakamura T, Kitamura F, Miyamoto N: Clinical application of transvenous mitral commissurotomy by a new balloon catheter. J thorac cardiovasc surg 87:394-402,1984.

8. Inoue K, Kitamura F, chikusa H, Miyamoto N: Atrial septostomy by anew balloon catheter. Jpn irc J 45:730-738, 1981.

9. Inoue K, A new balloon catheter for percutaneous transluminal angioplasty. AJR 144:1069-1071,1985

10. Inoue k, Nakamura T, Kitamura F, Miyamoto N: Nonoperative mitral commissurotomy by a new balloon catheter (abstr). Jpn Circ J 46:877, 1982.

11. Inoue k, Nakamura T, Kitamura F, Miyamoto N: Nonoperative mitral commissurotomy by a new balloon catheter (abstr). Jpn Circ J 46:877, 1982.

12. Inoue K, OwakiT, Nakamura T, Kitamura F, Miyamoto N: Clinical application of transvenous mitral commissurotomy by a new balloon catheter. J thorac cardiovasc surg 87:394-402, 1984.

13. Inoue K, OwakiT, Nakamura T, Kitamura F, Miyamoto N: Clinical application of transvenous mitral commissurotomy by a new balloon catheter. J thorac cardiovasc surg 87:394-402, 1984.

14. Vahanian A, Michel PL, Cornier B: A prospectiove evaluation of stepwise mitral balloon dilatation using the Inoue technique (abstr). Circulation 84 (suppl II):II-27, 1991.

15. Vahanian A, Michel PL, Cornier et al: results of percutaneous mitral commisssurotomy in 200 patients. Am J cardiol 63:847-852, 1989.

16. babic UU, Dorros G, pejcic p, et al: Percutaneous mitral valvoplasty: Retrograde, transarterial double-balloon technique utilizing the transeptal

approach. Cathet cardiovasc Diagn 14:229-237, 1988.

17. Vahanian A, Michel PL, Cornier et al: results of percutaneous mitral commisssurotomy in 200 patients. Am J cardiol 63:847-852, 1989.

18. Sapin P, Schroeder K, Smith M, et al. three dimensional echocardiographic measurement of left ventricular volume in vitro: comparison wioth two dimensional echocardiography and cineventriculography. J AM Coll Cardiol 1993;22:1530-7

19. Levine R, Handschumaker M, Sandilippo A, et al. Three dimensional echocardiographic reconstruction of the mitral valve, with implications for the diagnosis of mitral valve prolapse. Circulation 1989;80:589-98.

20. Popovic AD, stewart WJ. Echocardiographic evaluation of valvular stenosis: the gold standard for the next millennium? Echocardiography 2001;18:59-63.

21. Oh JK, Seward JB, tajik, AJ. The Echo Manual.2nd. Philadelphia: Lippincott-Raven,1999: 113-119.

22. Wang X-F, Li Z-A, Cheng TO, DengY-B, Zheng L-H, Hu G, Lu P. clinical application of three-dimensional transesophageal echocardiography. AM Heart J 1994;128:380-388.

23. Cheng To, Wang X-F, Zheng L-H, Z-A, Lu P. three dimensional transesophageal echocardiography in the diagnosis of mitral valve prolapse. Am Heart J 1994; 128:1218-1224.

24. Royes VP, Raju BS, Wynne J et al. Percutaneous balloon

valvuloplastycompared with opensurgical commisssurotomy for mitral stenosis. N Engl J Med 1994; 82:448-56.

25. Harrison JK, Wilson JS, Hearne Se, Bashore TM. Complications related to percutaneous transvenous mitral commissurotomy. Cathet cardiovasc Diagn 1994;2 Suppl 52-60.

26. Abascal VM, Wilkins GT,O'Shea JP et al. Preiction of successful outcome in 130 patients undergoing percutaneous balloon mitral valvuloplasty. Circulation 1990;82:448-056

27. Hogan K, Ramasamy K, Losorda DW, Isner JM. Pathology of mitral commisssurotomy performed with the inoue catheter: Implications for mechanisms and complications. Cathet Cardiovasc Diagn 1994;2 Suppl: 42-51.

28. Inoue K, Owaki T, Nakamura t, Kitamura f, Miyamoto N. Clinical application of transvenous mitral commiossurotomy by anew balloon catheter. J Thorac Cardiovasc Surg 1984;87:394-402.

29. Casal PN, Whitlow P, Currie PJ et al.Transesophageal echocardiography in percutaneous balloon valvuloplasty for miytral stenosis.Cleve Clin J Med 1989;56: 597-600

30. Iung B,Cormier B,Elias J et al.Usefulness of percutaneous miyral balloon commissurotomy during pregnancy.Am J Cardiol 1994: 73: 398-400

31. Ben Farhat M,Ayari M,Maatouk F et al.Percutaneous balloon versus surgical closed and open mitral commissurotomy:seven year follow up results of a randomized trial.Circulation 1998;97:245-50

32. Reid CL,Rahimtoola SH.The role of echocardiography/Doppler in catheter balloon treatment of adult with aortic and mitral stenosis.Circulation 1991;84:240-9

33. Otto CM,Davis KB,Holmes DR et al.Methodologic issues in clinical evalution of stensis severity in adults undergoing aortic and mitral balloon valvuloplasty.Am J Cardiol 1992;69:1607-16

34. Thomus JD,Wilkins GT,Choong CY et al.Inaccuracy of mitral pressure half time immediately after percutaneous mitral valvotomy:Dependence on mitral gradient and left atrial and ventricual compliance.Circulation 1998;78: 980-93

35. Smith MD, Wisenbaugh T,Grayburn PA et al. Value and limitation of Doppler pressur half time in quantifying mitral stensis: a comprison with micromanometer cather recording.Am J 1991;121:480-8

36. Kupferwasser I ,Mohr-Khaly S, Menzel T, et al.Qualification of mitral valve stenosis by three-dimensional transesophageal echocardiography.Int J Cardiac Imaging 1996;12:241-7

37. Binder Tm, Rosenhek R, Porenta G et al. Improved assessment of mitral valve stenosis by volumetric real-time three dimensional echocardiography. J Am Coll Cardiol 2000;36:1355-61.

38. Applebaum R, Kasliwal R, Kanojia A et al. Utility of three dimensional echocardiography during balloon mitral valvuloplasty. J Am Coll Cardiol 1998;32:1405-9.

39. Zamorano J, Cordeiro P, Sugeng L et al. Real time #D echocardiography for

rheumatic mitral valve stenosis evaluation: An accurate and novel approach. J Am Coll Cardiol 2004;43:2091-6.

40. Thomas JD, Wilkins GT, Chpoong CY, et al. Inaccuracy of mitral pressure half-time immediately after percutaneous mitral valvotomy. Dependence on transmitral gradient and left atrial and ventricular compliance. Circulation 1988;78:980-3.

GLOSSARY AND ACRONYMS

BMV-Balloon mitral valvotomy

PTMC-Percutaneous transvenous mitral valve commissurotomy

RT3DE-Real time three dimensional echocardiogram

PMC - Percutaneous mitral valve commissurotomy

TTE-Tran thoracic echocardiogram

TEE-Trans esophageal echocardiogram

LA-Left atrium

PHT –Pressure half time

MVA-Mitral valve area